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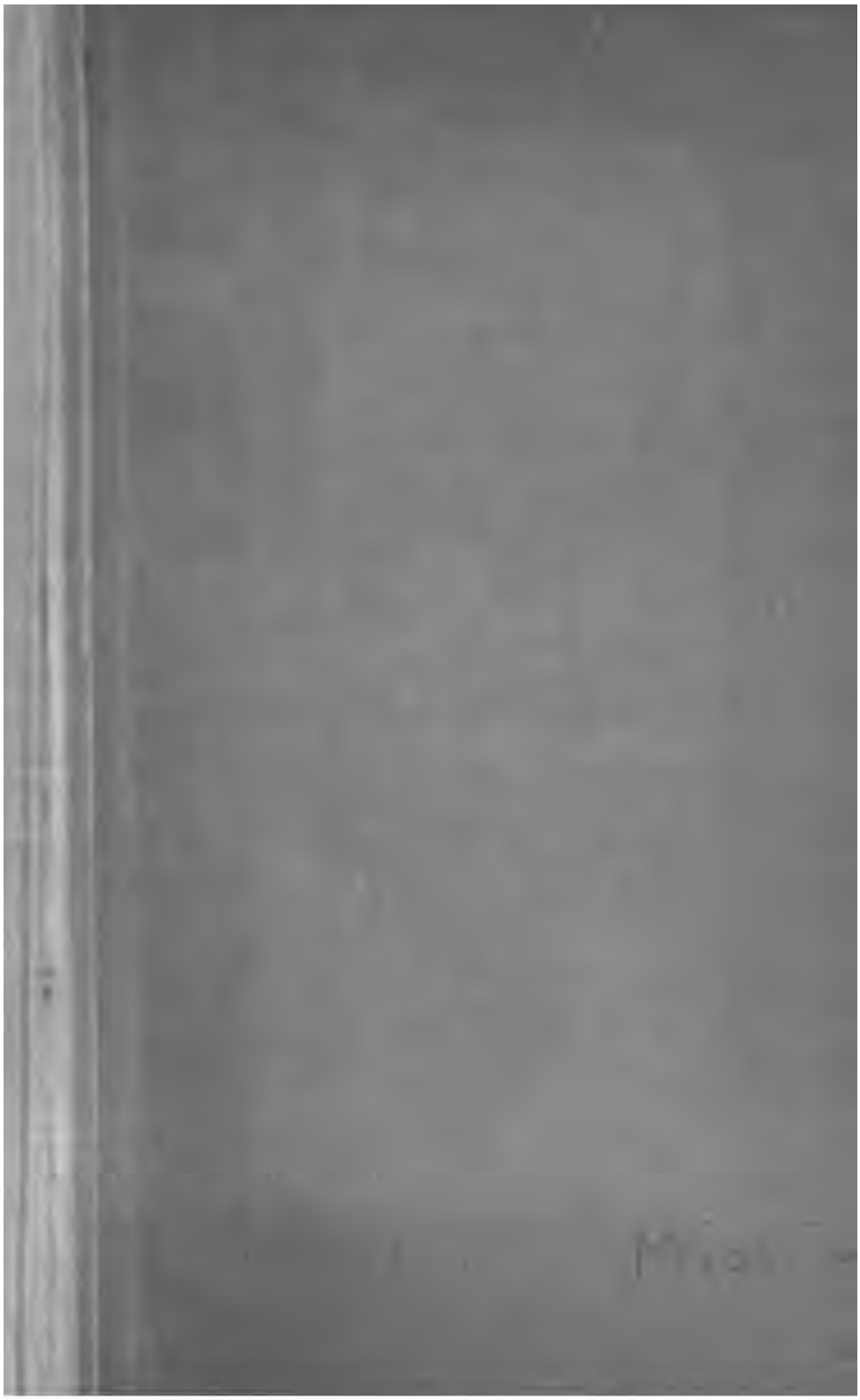

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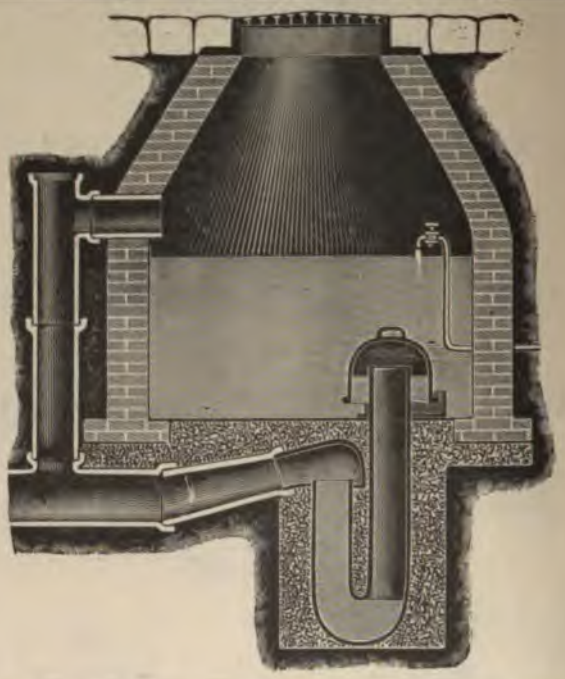

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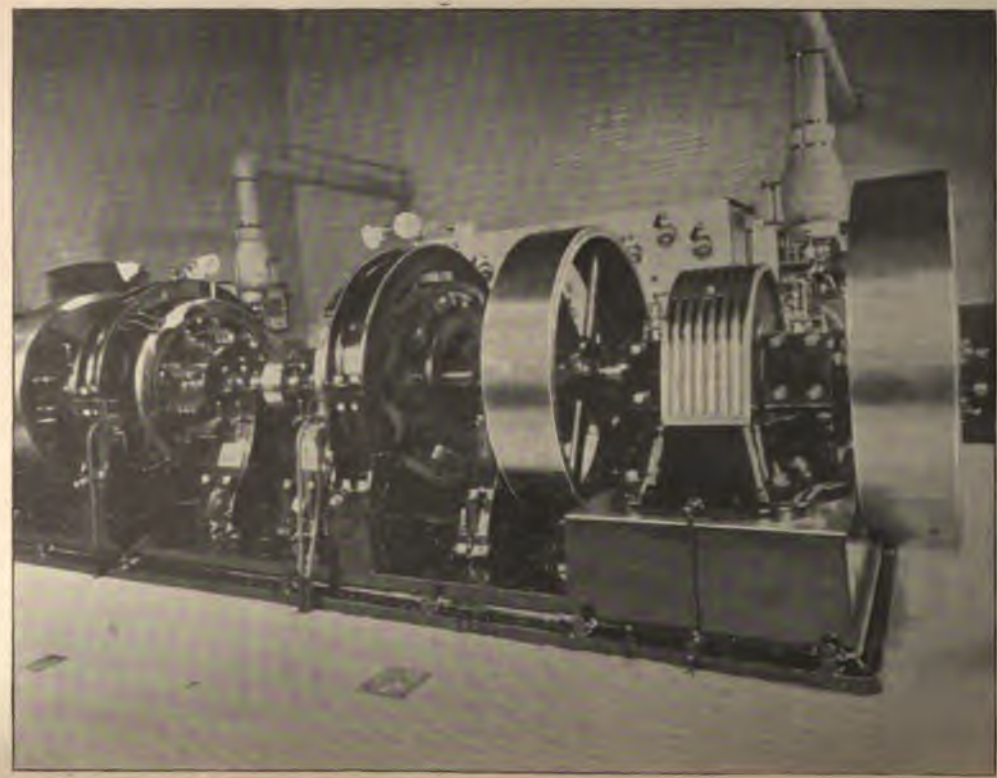

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## ELECTRIC LIGHTING PLANT.

HENRY S. CARHART

The electric lighting and power plant of the University of Michigan presents several features of interest which justify a brief description. The major part of it has been in operation since the middle of November, the auxiliary plant at the University hospitals has, however, only just been completed.

The main plant is on the campus in a wing of the boiler house from which sixteen buildings are heated. It consists of two 175 H. P. McEwen engines connected by means of the Arnold system to two 75 KW Thompson-Ryan dynamos. By the Arnold system either dynamo or both of them may be run from either engine. One of the advantages of this arrangement is that the dynamos can be tested by purely electrical methods, since they can very readily be disconnected from the engines.

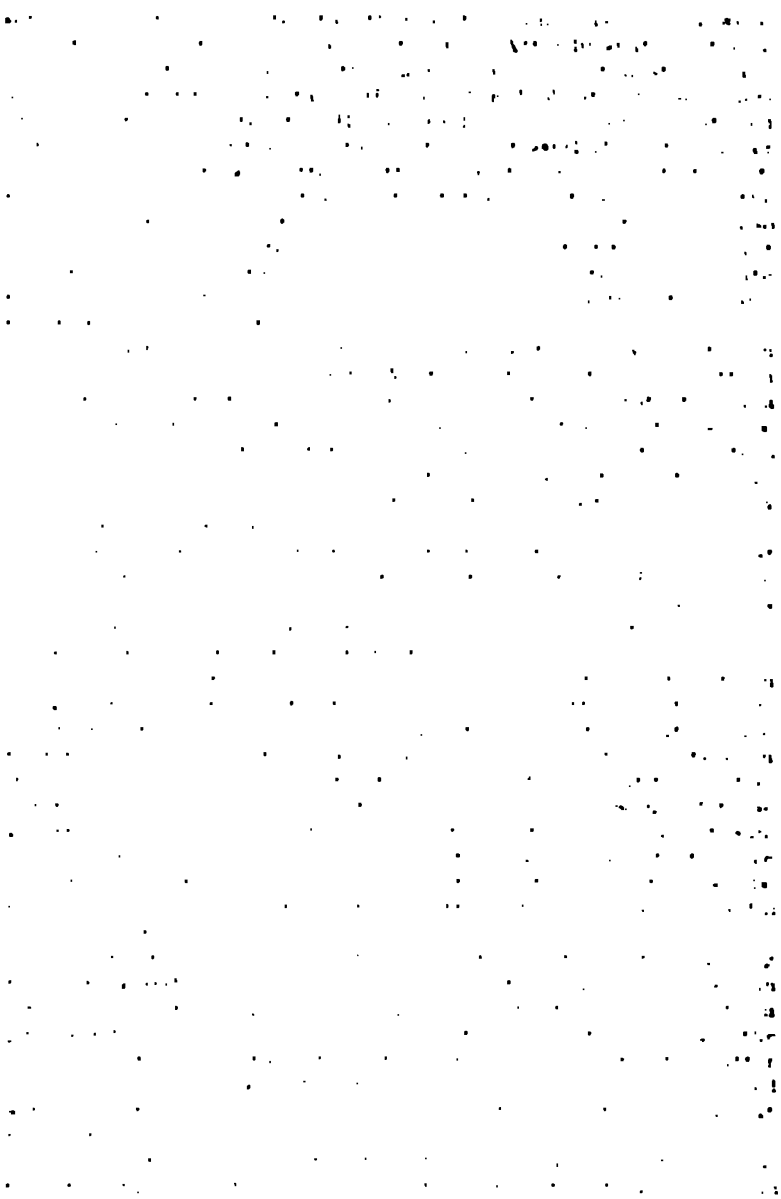
In the nineteen buildings on the campus lighted by this plant are [illegible] incandescent lamps and 21 enclosed arcs. There are nine more of the latter on the grounds. The observatory and the hospitals have [illegible] more incandescents. Another large building is under construction and this will bring the total number of incandescent lamps up to [illegible].

The system is two-wire 220 volt direct. It was adopted after mature deliberation in spite of the lower efficiency of the 220 as compared with the 110 volt lamp. The two prevailing reasons were the great distance of some of the buildings from the power house and the desirability of employing the same generators for power and lighting. The steam for heating the buildings is carried through a brick tunnel 5′ 6″ by 6′ 6″, extending from the power house round near or under all the buildings and back to the power house again, a distance of 2,800 feet. The largest buildings are at the greatest distance. The lighting mains had to be carried through this same tunnel. Hence the cost of the copper for a 110 volt system was almost prohibitive. It was also desirable to replace several small steam engines by electric motors in order to secure centralization of power. Other motors were needed at a considerable distance from the station. To these considerations must be added the fact that the observatory and the hospitals are nearly three-quarters of a mile from the power house, and economy dictates that these should be lighted from the main plant. It is much easier to do this with 220 volts than with 110.

To secure uniform pressure throughout the distribution on the campus the following plan was adopted. A pair of No. 000 mains were carried entirely around through the tunnel, forming two complete circles. To four points of these, as centres of the heaviest loads, are connected four pairs of feeders. Each pair runs directly from the bus bars through a switch on the switch board. The positive and negative cables are supported on opposite sides of the tunnel between special porcelain knobs. No greater difference of pressure than two volts has ever been observed at the ends of these feeders. Service wires run through fused switches directly from the mains to the several buildings. Buildings not located over the tunnel are reached by braided caoutchouc cables drawn into galvanized iron pipes. There is no insulation in the pipes. A few of the service cables are from 150 to 200 feet long. Thus far not the slightest trouble has been experienced, and not a single fuse has gone in the tunnel, either on feeders or service wires.

The buildings are all wired on the closet system. The closets have slate backs and are lined with heavy asbestos board. The fuses are all of extra length. No porcelain fuse blocks are used at these centres, and there are no fuses in the fixtures, except in porcelain rosettes and extension attachments. Single pole switches and the best grade of General Electric sockets are used throughout. Special precautions have been taken to secure safety by the use of nothing but the best insulation, abundance of flexible tubing, and lamp cord with double rubber insulation.

Current is carried to the hospitals by means of No. 000 cables a distance of 3,800 feet. To compensate for the drop in potential a series wound "booster," designed to raise the potential 50 volts at full load, is included in the circuit. The motor and generator of the



installation. It was designed by the Engineering Department of the University, and the work of installing it and of wiring the buildings has been done by students and recent graduates of the same department.

## PLANE TABLE.*

J. B. DAVIS, '68.

**46. Under Side of Rule.**—This should be a plane. In case of injury, the rule should be returned to the maker, to be tested; refitted, if necessary; and its bottom resurfaced, if found imperfect. The surface of the bottom of the rule is a vital part of the plane table,—quite as much so as either the spindle, or telescope axis. It should be cared for even more carefully than other parts as it is more exposed to injury. It may be injured by a fall; by crowding into a box the alidade does not quite fit; or by not being well packed in the box. If poorly packed it will be in danger during transportation. The rule may be bent, twisted, double bent, or both double bent and twisted. With some kinds of packing, the last injury is to be expected. Rules that are very light, or of open work, are especially liable to injury. The bottom of the rule should be continuous, like a plate. The packing of the alidade should be as perfect, and as secure, as can be devised. The metal for the rule, while such as does not disturb the magnetic needle, should be very stiff, and afterwards as light as can be. The rule may be ribbed above to make it lighter. It should be wide to give steadiness to the telescope axis, notwithstanding the increase in weight and that it will cover up more of the board. Rules are commonly too narrow: the telescope unsteady, sidewise: and the pointings untrustworthy. The same balance of precision running through the various parts of a plane table should be required, as is expected in a field transit.

**47. Edge of Rule.**—The edge of the rule should be straight. The metal rules, as received from instrument makers, are intended to be so. The person using a plane table, new to him, should test the edge of the rule as directed below, to assure himself that it is straight, or to find out if it has been injured. Ordinarily a rule with an imperfect edge should be returned to the maker to be put in shape. If the user cannot command the services of an instrument maker, in case of a crooked, or damaged, rule, something may be done to improve it, as mentioned below.

To test the straightness of the edge of the rule, place the alidade on a piece of paper,—drawing paper, if practicable,—stretched upon a plane surface. Draw a line, closely following the edge of the rule,

* Continued from THE TECHNIC, 1897, page 36.

with a sharp thin pointed knife, cutting a slight mark in the surface of the paper. Mark the ends of the rule, a pencil mark will do. Lay up the alidade. Place the rule on the opposite side of the knife mark. Bring the ends of the rule to the same places on the line as before, and set the edge of the rule at the ends precisely to the knife marks on the paper. Use a magnifying glass for this. Draw a second line with the knife, as before. Remove the alidade. See if the marks coincide. If they do not their deviations will indicate the imperfections in the edge of the rule. If they do coincide the rule is near enough straight for use on the plane table.

If it needs it, the rule may be carefully ground on a water grindstone or rubbed down with emery on a piece of soft wood, or scraped with the back of a knife ground to a square corner. By carefully working with it it may be restored to a condition fit to use. This is in most cases much less delay and expense than stopping the work while you send the rule to some distant maker.

No matter what the two edges of the rule ought to be straight and [illegible].

**48 Surface of Board.** This should be a plane. Apply a straight [illegible] from the alidade assembly to the surface of the [illegible] from [illegible] and [illegible] these [illegible] straight edges should fit the surface of the board everywhere. If it does not work the surface of the board down with a [illegible] and sandpaper [illegible] straight edge will fit as [illegible].

**49 Levels on the Rule.** [illegible] the surface of the rule for the purpose of [illegible] under [illegible] and [illegible].

[illegible] Set up the plane table. Level it as [illegible]. Place a [illegible] over a pair [illegible] Draw a line [illegible] edge of [illegible]. Mark [illegible] ends of the [illegible]. If [illegible] set [illegible] the [illegible].

[illegible] Reverse it. If [illegible] Reverse it. Place [illegible] Now [illegible] Reverse it. Place [illegible] Now [illegible] Place [illegible] Now [illegible] Place [illegible] Now [illegible]

the corrections and tests, in this manner, till no deviation appears when the test is made.

Check screws upon the adjusting screws of the level tubes (sometimes placed in the end plugs of the level tubes) must be released before making the correction. These check screws keep the level tubes longer in adjustment, but may give annoyance in making the adjustment. Do not screw them too tight. Test the adjustment, and see that it is correct, after the check screws are set.

**50. Board at Right Angles to Spindle.**—This is for the purpose of having the surface of the board remain level during its revolution on the spindle. This is necessary in orienting the plane table, or in any case requiring the table to be turned about its spindle. The top surface of the board is set square to the spindle.

The board should have a true top surface. The level tubes on the rule should be in adjustment.

If the board is much out of square with its spindle, it may be shown by setting up the table where the board can be revolved on its spindle so its surface is just touched, near its outer edge, by a pencil point, or a pointed stick. The board should be connected to its fastenings so this mechanical test will show it to be square to the spindle.

Set up the plane table firmly. Level it carefully with the spindle unclamped, and the alidade standing over a pair of levelling screws.

Reverse the board on its spindle. See if the bubbles read level. Reverse the board back to its first position. See if the bubbles again read level. Repeat these trials, making the necessary corrections in the setting, or levelling, of the plane table, till the bubbles will surely read level again when the board is returned to its first position. Then reverse the board, as at first, and note the deviations of the bubbles from level readings.

Change the bearings of the connections beneath the board so as to correct one-half the apparent level error. Sometimes the board is connected with the tripod head by means of a brass plate screwed centrally to its under side,—sometimes by three radial brass arms, connected centrally to the board by screws at their ends. Whatever the plan, the bearings of these connections should be changed by working down the wood slightly, or inserting very thin washers of paper, or some similar device for making this change. The board will need to be taken off the tripod head to do this.

Level the plane table carefully again. Test the adjustment as at first. Repeat the corrections and tests, in this manner, till the bubbles will stand level during an entire revolution of the board on its spindle.

51. The preceding adjustments can better be made under cover wherever there is a firm footing for the plane table, as in a well lighted basement or cellar.

**c) Line of Sight at Right Angles with Telescope Axis.** It is for [illegible] line of sight moves in a plane when the [illegible] There are two cases. First, when [illegible] Second, when it cannot. [illegible] the circle of the telescope axis [illegible] telescope without turnover, [illegible] It is made into the instrument [illegible] examinations made for [illegible] required in a [illegible] more easily made when the [illegible] for transit, the wyes open in this [illegible] telescope axis adjustments made [illegible] of the telescope itself. By making [illegible] without [illegible] the adjustment of the axis parallel [illegible] made easy.

**d) Line of Sight at Right Angles With Telescope Axis. Closed Wyes.** [illegible] Look for [illegible] the second [illegible] at once. [illegible] the [illegible] the [illegible] the

spindle slow motion screw, so the line of sight will strike the first two marks. Should the board appear to be not quite level, level it. Finally set the alidade so that the line of sight strikes both the first marks and the bubbles both read level. Reverse the telescope on its axis and see if the third mark is in line. Turn the telescope back to the first marks, as before, and, by the same means, make sure the line of sight will strike those marks. Then reverse the telescope, as at first, and note the deviation of the line of sight from the third mark.

Correct, by estimation, one-fourth of the deviation of the vertical cross wire by means of the screws at right angles with it that hold the cross wires in the telescope tube. Whether the telescope shows objects right side up, or not, turn these screws as if to increase the apparent deviation.. Loosen the screw permitting the desired movement before turning the other. Leave the screws under a gentle, even, strain. If the deviation is large, loosen the other pair of screws slightly, but have a care not to get the vertical cross wire inclined.

Set the line of sight again upon the first two marks, as in the beginning. Repeat the tests, corrections and tests, till no deviation appears when the test is made.

**54. Line of Sight at Right Angles With Telescope Axis. Open Wyes.**—A place to set the plane table in is needed where a well defined fixed mark can be readily found at as great a distance away as the telescope will show it distinctly, so pointings to it can be made with precision. The mark should be about on a level with the table.

Set up the plane table firmly in a suitable place. Level it carefully. Place, or leave, the alidade central on the table. Open the wye clips. Look for a distant, well defined, fixed mark. Direct the telescope to look at the mark. Clamp the spindle. Set the line of sight on the mark with the spindle slow motion screw. Lift the telescope out of the wyes. Turn it over, keeping the objective towards the mark. Replace it in the wyes with the telescope axis reversed, the telescope the other side up, and looking to the mark. See if the line of sight strikes the mark. Lift the telescope, and replace it in its first position. See if the line of sight strikes the mark again. Repeat these trials, making the necessary corrections in the setting or levelling of the instrument until the line of sight will surely strike the mark again when returned to its first position. Then reverse the telescope as at first and leave it so as to show the deviation of the line of sight from the mark.

Correct, by estimation, one-half the apparent deviation of the vertical cross wire from the mark, by means of the screws at right angles with it that hold the cross wires in the telescope tube. Whether the telescope shows objects right side up, or not, turn these screws as if to increase the apparent deviation. Loosen the screw permitting the desired movement before turning the other. Leave the screws under a gentle, even strain. If the deviation is large,

loosen the other pair of screws slightly, but have a care not to get the vertical cross wire inclined.

Set the line of sight again upon the mark. Repeat the tests, corrections and tests, till the line of sight will strike the mark when the test is made.

**55 Striding Level.** As noted in 52 a striding level may be useful. It may be employed to improve the precision and trustworthiness of the measurements of vertical angles, and facilitate the adjustment of the telescope axis parallel to the under side of the rule. This level itself should be kept in adjustment. The method of adjustment is as follows:

Set up the plane table firmly. Level it carefully. Place, or leave the alidade central on the board. Clamp the spindle with the telescope axis over a levelling screw. Place the striding level on the telescope axis. See if it reads level. If not, change the setting of the levelling screws till it will stand level. Lift off the striding level. Reverse it. Replace it in reversed position. See if it reads level. Return it to its first position. See if it reads level again. Repeat these trials, making the necessary changes in the setting and levelling of the instrument, till the bubble of the striding level will remain central when returned to its first position. Then reverse the striding level as at first. Leave it now to show the elevation of its feet from a level reading.

Correct by estimation one-half the deviation of the bubble from the level reading by means of the adjusting screws which connect the axis of the striding level to its base.

Test the adjustment as before. Repeat the tests, corrections and tests, till the bubble will read level when the test is made.

If, when the adjustment stand the striding level vertically over the marks. Incline it. If inclined it may show the adjustment apparently imperfect. This requires a separate adjustment made by bringing the axis of the level tube into a plane parallel to the line of the points of support of the feet of the striding level.

Do not set the striding level aside when first made. Test and adjust it as perfect as practicable.

Invert the striding level, right end on the left. Return it to its first position. See if the bubble again reads level. If not, by the adjustment, correct for deviation about the same amount. Return it again to its first position. See if the bubble again reads level. Repeat these trials, making the necessary correction on the setting of the axis of the plane table, till the bubble will read level again when the level is returned to its first position and stands at the same reading when the striding level is on the plane table at first and when it is inverted. Then reverse the striding level as at first and note the deviation of the bubble from a level reading. In case it is not convenient to invert the level, test and note the deviation.

By means of the screws for adjusting the inclination of the plane table set it to show the same elevation on the same [illegible]

same inclination either way from its vertical stand, when tested as above described.

The bubble should read level in all three positions. If it does not the bore of the glass tube is not uniform, and it should be replaced by a perfect one at the first opportunity. In using such a striding level be very careful to stand it plumb on its feet.

This adjustment, and the preceding, need to be made alternately together when first the bubble tube is attached to its base.

If, for any reason, the bubble tube has to be disconnected from its base, loosen but one of the sidewise screws and notice how tight it is. Likewise, if there is a check screw to the vertical adjustment, leave it alone,—only unscrew the adjusting screw. When the bubble tube is again restored to its connections with its base it can be set almost in its proper place by bringing the loosened screws to their bearings again, and not require so much adjustment.

56. **Telescope Axis Parallel to Under Side of Rule.**—This adjustment is for the purpose of making the line of sight revolve in a plane perpendicular to the under side of the rule. When the plane table is set up and levelled, the line of sight will revolve in a vertical plane, when it is at right angles to the telescope axis, and that axis parallel to the under side of the rule. This adjustment places the line of the telescope axis parallel to the under side of the rule.

The objective slide should be in good line. The levels on the rule should be in adjustment. With closed wyes, the line of sight should be in adjustment at right angles with the telescope axis.

57. **With Closed Wyes,** set up the table as near some high, well defined, fixed, mark as it can stand and that mark be easily observed with the telescope. Place the alidade central on the table, and level it carefully. Set the line of sight on the high mark by means of the spindle clamp and slow motion screw. Leave the spindle clamp secure. See that the bubbles both read level. Correct the setting of the levelling screws slightly, and the pointing also, if needed, till the line of sight will strike the mark and the bubbles stand level. Turn the objective downwards till the line of sight points at nearly the same angle below the horizon that it did above. Find, or fix, two marks, near by, in apparent line, ten or fifteen feet apart, with little or no change in the pointing of the telescope. Make sure of the stability of the table, alidade, and telescope by repeated pointings upon the upper and lower marks, and by watching the levels. Make any necessary changes in the setting or levelling of the table to secure this.

Take up the alidade. Reverse it. Replace it on the table. Reverse the telescope. Level, if needed. Set the line of sight to range upon the two lower marks, using the spindle clamp and slow motion screw. Level, more carefully, if needed. Perfect the pointing on the lower marks.

See if the upper mark is now in apparent line. Repeat the point-

**58 With Open Wyes.**

**59 Adjusting the Telescope Axis Horizontally.**

one, but both should stand level. If a striding level is used fix the support so this will stand level when placed on the telescope axis. The alidade should stand firm and steady on the support. From this support the line of sight should strike a distant, well defined, fixed mark. Have ready some needles, and a needle point. Put a paper on the board.

Set up the table firmly about twenty feet from the alidade support, so the line from it to the distant mark will cross the board centrally, and with one pair of levelling screws crosswise of this line. Clamp the spindle securely. Level the table carefully. Place the alidade on the prepared support. See that it stands level and steady on the support, when the line of sight strikes the distant mark. Use the hands to make the pointing on the mark. Locate two points in line on the table with the needle point, and prick them down, a little less than the length of the rule apart. Also locate a point (on a stake perhaps) in line, forty or fifty feet beyond the table. Test these locations by repeated pointings to the distant mark,—also notice the levels, and see that they remain level.

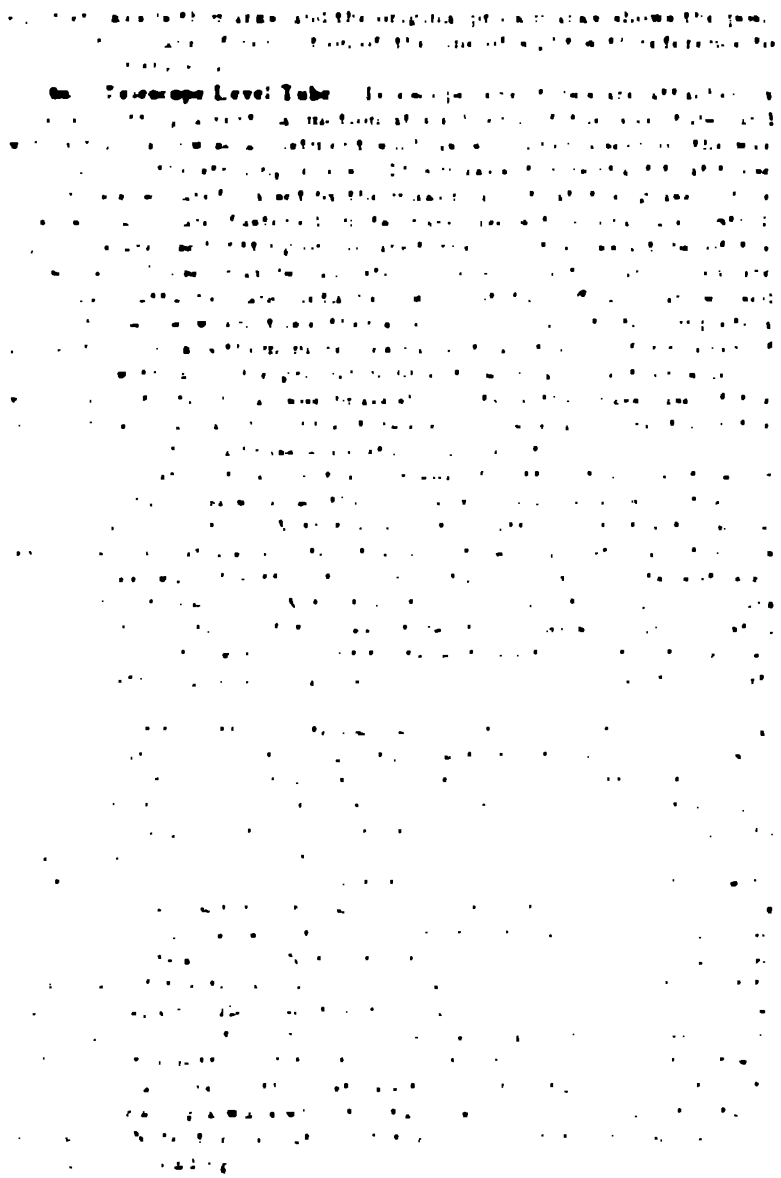
Transfer the alidade forward, as it stands, to the table, and bring the edge of the rule to the points marked on the paper. Be especially careful not to move the table in any way. See if the level bubbles on the rule read level. If not, level the table again, and relocate all three of the points, as at first. So continue to do until the level bubbles on the rule read level when the alidade is transferred forward to the board and the edge of the rule brought to the prick marks on the paper.

See if the line of sight strikes the distant and near by marks, or at the same distance from and on the same side of them.

By means of the device provided for controlling the direction of the telescope axis in a horizontal plane, set this axis so the line of sight will strike the marks named, or pass the same distance from, and on the same side of both, when the edge of the rule is at the prick marks on the paper.

After the adjustment seems perfect return the alidade to the support; with the hands make the line of sight strike both marks beyond the table; and try the prick marks on the paper for line. If they are no longer on line the table has been moved. Level the table again if it needs it. Repeat the work. Continue these locations, adjustments, and tests, till all four points are in line at the final test.

In making this adjustment the alidade may be set over parallel to the line of the two prick marks on the paper, by pricking off equal distances from them, so that, after repeated trials, the line of sight will strike both marks when the telescope axis is adjusted. The equal distances must be very carefully pricked off to make sure they are really precisely equal. This process saves any estimation of the distances between the line of sight and the two forward marks. The distance finally found between the edge of the rule, when the line of



Correct one-half of this deviation by the slow motion screw to t telescope axis.

Level and reverse the table again, as before.

Repeat these operations till the telescope level will read level either the first, or the reversed position, of the table.

Turn the table one-quarter round and level it again, as abo set forth.

By repeated trials, making the necessary corrections in the s ting of the table and the telescope level, as above directed, make tl level read level for any position of the table when turned on spindle.

*For setting the line of sight level.* Level the table as above direct Leave the telescope clamped. Measure off, each way from the cent of the table, the same distance, say 150′ or 200′, and drive a stake t firm, at the end of each measurement. Number these stakes 1 and See that the table is level and stands steady. Take accurate r readings on the tops of the stakes. Subtract the reading on 1 from t reading on 2 and preserve the sign of the result, + or −. Call tl result $k$.

Move the table to a place, a short distance, say 30′, beyond sta 1, carrying the telescope clamped as last used. Set up the table he and level it as directed above. Take a rod reading, $r_1$, on stake 1 a another, $r_2$, on stake 2, just as the first ones were taken. Reco these with their numbers. Find $r_2 - r_1$, noting the sign. Call tl $k'$. See if $k = k'$. Make sure of the whole work.

If $k = k'$ the line of sight is horizontal and the level tube in a justment. If $k'$ does not equal $k$, measure the distances from t center of the table to stake 1, $d_1$, and to stake 2, $d_2$. Find a rod rea ing, $R_2$, for stake 2 by the following equation, observing all signs:

$$R_2 = r_2 + \frac{k - k'}{d_2 - d_1} d_2 \ldots\ldots\ldots\ldots\ldots\ldots$$

Hold up the rod on stake 2 set at this reading, $R_2$, if a targ rod), and by means of the slow motion screw to the telescope axis, s the line of sight so it will give the rod reading, $R_2$, on stake 2.

Test by taking a new rod reading, $R_1$, on 1. Find $R_2 - R_1$, obser ing the sign of the result. See if the result very nearly equals $k$.

Proceed with these trials and tests till the line of sight is set that $R_2 - R_1$ at a test, equals $k$, or so near it that the experimen show it to be useless to try further.

*For setting the level tube.* Set the level tube to read level by mea of the nuts at one end of it. Start that nut first that will permit tl desired movement. Leave the nuts under a gentle even strain.

Test the level tube adjustment by additional rod readings a finally set it so that $R_2 - R_1 = k$ when the bubble stands level,—or near this condition as can be.

If this is considerably less than before, for the other side of the bubble tube, make the same observations and adjustments for this side as above detailed for the other.

Release the necessary clamps, reverse the telescope about its axis and the table on its spindle, and make the tests just above noted, anew for the side of the bubble tube which is again uppermost.

Repeat these trials, adjustments, and tests, till the telescope level, and the horizontal cross wire, are so set, that the line of sight will be level when the bubble reads level whichever side up the bubble tube may be, as shown by rod readings on both stakes.

If persistant trial under favorable conditions of light, seeing, temperature, and steadiness, does not complete these adjustments so they will bear the test imposed, or very nearly so, repeat the work and make these adjustments so the two sides of the bubble tube will read the same (not a level reading) when the line of sight is level. Record this reading, and fasten it in the instrument box.

By these last adjustments the horizontal cross wire is set nearer its proper place in the telescope tube, if not at that place. The trouble of these adjustments show the value of such a level tube in such a place. Once the level tube is proven to be ground alike on both sides it makes matters somewhat easier. Even with a perfect level tube there can be no sidewise adjustment and the device is not nearly as perfect as that of a striding level standing on collars turned on the body tube of the telescope.

*Horizontal cross wire. Striding telescope level.*

*Preparations.*—Set up the table firmly. Level it carefully with the rule levels. Clamp the spindle so the telescope will stand over a levelling screw. Clamp the telescope level,—as shown by its striding level. Adjust the striding level fully as directed in 55. Level the table by means of the telescope level as directed above. See, at the last, that the striding telescope level remains in adjustment with respect to its own feet.

Direct the telescope to some object and find a mark on it in line with the horizontal cross wire when the table is carefully levelled by the telescope level, and that level is in good adjustment. Prove the steps and make sure the conditions are favorable.

Release the necessary clamps. Reverse the telescope about its axis, and reverse the table on its spindle. Set the telescope level as before. Be sure the striding level keeps its adjustment. Note the deviation of the horizontal cross wire from the mark it covered before.

Move the horizontal cross wire by means of the screws at right angles with it, that hold the cross wires in the telescope tube, and set it so it will cover a place midway between the two marks above noted, when the telescope is level.

Test the adjustment as at first. Repeat the test, correction, and test, till the horizontal cross wire will cover the same mark with the telescope either side up, and level.

[illegible] arrangement of a telescope [illegible] the best for general use. The same [illegible] may be made to fit the transit axis also.

61 **Vertical Circle Vernier.** If the telescope is provided with a [illegible] vertical [illegible] 60 it may be put in adjustment by the [illegible] the same way as directed for the horizontal axis. The line of sight [illegible] and the vernier of the vertical circle set to [illegible] when the line of sight is level. This is best, when practicable, [illegible]

[illegible] have a vertical arc in the place of a [illegible] have two opposite verniers for the vertical circle, while [illegible] have two opposite verniers set horizontally and two opposite [illegible] of a vertical circle. With these verniers [illegible] that of observing [illegible] apart or sufficiently near so that [illegible] a considerable [illegible] of instrumental precision to [illegible] of observation, and some method of [illegible] considered. The [illegible] to take up numerous [illegible] on different parts of the [illegible] to [illegible] and to record and compare [illegible]

[illegible] 60 the [illegible] by the [illegible] It is not [illegible] [illegible] In [illegible] that the [illegible] [illegible] 60 [illegible] For [illegible] [illegible] 60 [illegible] for [illegible] [illegible] [illegible]

[illegible] [illegible] [illegible] [

Move the verniers, by means of the device provided for that purpose, leaving the telescope and vertical circle clamped, and set them to read 0° 00′ 00″ and 180° 00′ 00″. See if the line of sight is still pointing midway between the two former pointings. If not, repeat the setting of the verniers till they will read 0° 00′ 00″ and 180° 00′ 00″ with the line of sight so set.

Set the level to the verniers to read level, if there is one, after setting them to read 0° 00′ 00″ and 180° 00′ 00″, as above.

Test the adjustment as at first. Repeat the preparations, tests, corrections, preparations, and tests, till the line of sight will strike the same mark whichever side up the telescope may be when the verniers are set for a level line of sight, and the table carefully levelled, —or as nearly as can be to these conditions.

In case verniers cannot be conveniently set to read 0° 00′ 00″ and 180° 00′ 00″, record, and preserve, the readings corresponding to a level position of the line of sight.

**62. Line of Sight.**—If the alidade has a telescope with a level attached to its body tube, it being in adjustment with respect to the line of sight, and it is necessary to adjust the vertical cross wire, as in 53 or 54, some work may be saved by levelling the table for that adjustment with the telescope level, setting the line of sight level, and observing some mark in line with the horizontal cross wire, before beginning the adjustment of the vertical wire. After the vertical wire is adjusted set the horizontal wire on the same mark, first seeing that the table is as well levelled, as before, and adjust the telescope level to read level again, in case it needs it.

It is epecially easy to derange the cross wires whenever all four cross wire screws are loosened.

If the telescope level is a striding level it is so little work to adjust the horizontal cross wire that it had better be done instead of depending on any such device as here given.

**63. Centering the Eye-piece.**—This is for the purpose of clear vision, as one might center a magnifying glass more carefully over an object to be viewed. Frequently there is no way provided for making this adjustment, and none is needed.

Direct the telescope to the light,—artificial light, or the sky, will do. By means of the four screws like, or similar, to the cross wire screws, that hold the ring in the body tube of the telescope, in which the inner end of the eye-piece slides, set that ring so the cross wires divide the field of view symmetrically.

**64. Objective Slide.**—No adjustment of the objective slide should be needed. At this point the skill of the maker should be manifest. A test is given below instead of an adjustment. This test will indicate how perfectly the slide is fitted, if the objective is well mounted, or how well the objective is mounted if the slide is well fitted. Two imperfections may be present, or but one of them. An adjustment does not correct the difficulty. It partly hides it.

set up the plane table where a row of stakes can be lined by the telescope without a motion of any kind except changing the focus of the objective. Place the alidade centrally on the table and clamp the telescope in position to do the lining. Weight the rule if there is fear of its slipping or insert pins about it in the board. Line out a row of stakes at measured intervals of fifty feet, to 1,000 or 1,500 feet away. Use a foresight at the end of the line, or beyond it, to keep the telescope steady in. Mark points on these stakes precisely in line and at the measured distances apart.

Move the plane table to the other end of the line and by trial set it so that the line of sight covers the end marks with no motion but focusing the objective. Leave the telescope unmoved, and clamped. Locate a new set of points at the same places as before. Note their deviations. There should be none theoretically.

This is a test with respect to line. A similar test with respect to level may be made by setting points on the sides of tall stakes in the line of the horizontal cross wire. The horizontal cross wire cannot be exactly set to cover the end marks in the second position of the telescope, but the telescope by means of the slow motion screw to elevation depression of sight by the horizontal cross wire will pass at a small distance from and on the same side of the end marks. Make a note of this. Measure the spaces between these and the end marks. They should be equal theoretically.

J. B. DAVIS '98.

XXX, Ann Arbor Mich., June 1, 14.

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## WHITE LEAD.

J. J. MORRMAN '01.

Some people fear the importance of commercial White Lead and its relation to the lead in the manufacture of other goods a matter not even known that to the base of a paint having any whatever except the possible artistic value. Generally speaking, people do not know what to look for in a paint and have but a very vague idea as to its physical and chemical properties and are therefore easily compelled to use what is White Lead.

White Lead is the commercial name of a basic carbonate of lead having the chemical formula $2PbCO_3, Pb(OH)_2$. Such would be quite a simple matter of fact, but this basic carbonate and others are the parts of a mixture part hydrate or hydroxide. The latter we have seen to be the more desirable. The former for the reason that White Lead with a ratio of the formula $2PbCO_3, Pb(OH)_2$ is decomposed into, natural

times an analysis reveals the normal carbonate, $P\,b\,C\,O_3$: again, five parts of carbonate to two hydrate: the proportion of carbonate and hydrate varying from equal parts of each, to the normal carbonate. The best is, however, of the formula $2\,P\,b\,C\,O_3\,P\,b\,H_2\,O_2$ or $3\,P\,b\,C\,O_3\,P\,b\,H_2\,O_2$, and possesses great opacity and covering properties, drying quickly and hard when applied after being mixed with linseed oil, and forming an elastic coating or paint. It is the hydrate that unites with the oil, giving the elasticity, but hydrate of lead alone would have little opacity, this being imparted by the carbonates which forms an emulsion with the oil. Both are necessary: pure hydrate of lead would turn yellow and have no opacity; pure carbonate would have opacity but no elasticity and would chalk off.

The manufacture of White Lead consists in forming from metallic lead basic acetates by action of acetic acid on excess of lead metal, and the precipitation of basic carbonate, i. e., White Lead, from the basic acetates by means of carbon dioxide. Excess of acid would produce the normal acetate, from which basic acetates could be formed, or the basic carbonate, i. e., White Lead, could be formed by the combined action of carbon-dioxide and water on the normal acetate. To formulate:

1. $P\,b + O = P\,b\,O$.
2. $P\,b\,O + C_2\,H_4\,O_2 = P\,b\,(O\,H)\,(C_2\,H_3\,O_2)$.
3. $P\,b + C_2\,H_4\,O_2 + H_2\,O = P\,b\,(O\,H)\,C_2\,H_3\,O_2) + H_2$.
4. $P\,b\,O + 2\,C_2\,H_4\,O_2 = P\,b\,(C_2\,H_3\,O_2)_2 + H_2\,O$.
5. $P\,b + 2\,C_2\,H_4\,O_2 = P\,b\,(C_2\,H_3\,O_2)_2 + H_2$.
6. $H_2 + O = H_2\,O$.
7. $3\,P\,b\,O + 2\,C_2\,H_4\,O_2 + H_2\,O = P\,b_3\,(O\,H)_4\,(C_2\,H_3\,O_2)_2$.
8. $6\,P\,b\,(O\,H)\,(C_2\,H_3\,O_2) + 2\,C\,O_2 = 2\,P\,b\,C\,O_3\,P\,b\,(O\,H)_2 + 3\,P\,b\,(C_2\,H_3\,O_2)_2 + H_2\,O$.

Referring to the above reactions you will note the basic acetate formed in 2 and 3, said acetate being the basic acetate formed with ½ the amount of acid necessary for producing the normal acetate (see 4 and 5), the former being the result of action on lead oxide, the latter on the lead metal, the oxide being formed by the action of the air on the metal as indicated in 1. In 6, I merely indicate the disposition of the hydrogen formed in 3, in addition to the basic acetate. Lead oxide is more easily soluble in the acid than is the lead metal, but whether the acid acts upon the oxide or the metal, the basic acetate is formed, provided there be an excess of oxide or metal. The ½ acid salt, or that formed with ½ the amount of acid necessary for forming the normal acetate, is soluble in water as well as the acid salts formed with ½ the amount of acid necessary for forming the normal acetate, already referred to. I do not think, however, enough lead metal would dissolve in the acid to form the ½ acid salt, but such would be possible with lead oxide, as in 7, which basic acetate would answer the purpose.

Acting on the basic acetate formed in 2 and 3 with the carbon-dioxide we have basic carbonate, i. e., White Lead, normal acetate as per 4. The normal acetate thus formed could be inverted into basic acetates, and then acted upon by carbon-dioxide, as in 5, but is probably changed into basic carbonate, i. e., White Lead, by the combined action of carbon-dioxide and water, freeing acetic acid which again acts upon the excess of lead metal.

It must not be imagined that in order to manufacture White Lead for commercial purposes all one has to do is to look at the above formulæ, take lead metal, acid and water, at the ratio of 207 to 60 and 18 the molecular weights in 1, go ahead and produce basic acetate, and the product White Lead. As a matter of fact the ratio of acid to lead used would be less than 1 to 30.

There are only two processes used to any extent in the United States, namely, The Dutch process, so called, and the Carter or American process, so called.

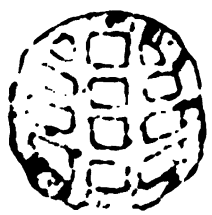

Fig. 1.

The Dutch Process, so called, is a modification of that process and consists first in a physical change in the lead metal from its pigs or bars into buckles. These buckles are produced by passing strips of metal, as they are cast, between a pair of rolls, one of which is corrugated, the corrugations being from one eighth to one quarter of an inch deep, as the plate is rolled. They are not sent direct into corroding houses, as shown in figure 1, the idea being to increase the surface of the lead metal to the corrosive agent. This would be the case if the metal were used in the form of unperforated sheets of the same thickness, although the latter would be better than pigs or bars. These buckles are made by a machine which it is not necessary to describe. Suffice it to say that the lead metal as received from refining furnaces is melted and run into chain carried by machines which carry the buckles away.

These buckles are placed in earthenware pots about 8 inches in depth of which are shown in figure 2 which however represents a pot in section containing corroded buckles. These earthenware pots are about seven or eight inches high, five to five and one-half inches in diameter at the top and of sufficient size to hold the buckles. In the bottom of these pots is placed a quantity of acetic acid that used being commercial acid 6 to 8 per cent strength, to contain from 2 to 4 per cent of acid. These pots are made with these proportions in the following manner:

Fig. 2.

A chamber, generally with brick walls and bottom, say 20 by 30 feet floor surface, is covered to the depth of two or three feet with spent tan, in which fermentation has begun. The earthen

tanners' refuse, which is taken from the leaches after the tannin or tannic acid has been extracted from the oak, hemlock or other bark. In fact, one corroder who employs the Dutch Process, extracts the tannin from the bark, marketing it in Europe, and using the spent tan for corroding purposes. The spent tan in the chamber is tapped down and leveled, and on this surface the earthenware pots are set close together, containing the acid and the lead metal in the form of buckles. This layer of earthenware pots does not cover the entire surface of the spent tan. The space left between this layer of pots and the walls of the chamber is from 6 to 12 inches. The outside rows of pots are higher, and upon these pots common boards are laid, covering the entire layer; or blocks may be used for the purpose of supporting these boards, the blocks being about two inches higher than the pots so as to leave about that space between the layer and the boards. The space between the walls of the chamber and the earthenware pots is filled with spent tan, and on the boards another layer is built in similar manner, except that the spent tan is but 10 or 12 inches in depth rather than three feet, as in the case of the first layer. A succession of these layers to the height of, say 25 feet, is termed a stack. The space between the pots and the walls of the chamber is filled in with the spent tan and the top is covered with it. There is an opening, of course, in the front of the chamber to permit of the building of the stack. This is closed with ordinary boards as the stack progresses in height.

The spent tan already in a state of fermentation, gives off carbon-dioxide and heats the acetate acid in the bottom of the pots, causing it to vaporize. The acetic acid vapors act on the buckles, forming the basic acetate upon which the carbon-dioxide acts. The time necessary to corrode a stack by this method is from three to four months: even then a stack may be torn down and the percentage of corrosion found to be very small. It is a drawback that the lead can be examined during the process of corrosion. The temperature in these stacks varies, it being almost impossible to keep it uniform, the temperature rising to 140 or 150 degrees F., and again dropping so low that action ceases. Some stacks are provided with steam pipes for the purpose of generating sufficient heat to keep up chemical action. The amount of lead in a stack varies, of course, according to the size of the chamber and the height of the stack: there might be three tons of lead to a layer or seven tons. Some stacks contain as much as ninety tons, although such a stack would require a chamber with a floor surface greater than that mentioned above, unless it was built to an unusual height.

After the chamber has remained unvisited for three or four months, it is torn down, the pots containing buckles as shown in figure 2, also more or less spent tan that sifted through the boards when each successive layer was being removed. The percentage of corrosion in the Dutch Process does not average 70%, and oftentimes falls

as low as 50%. The corroded portion of the buckles is of a hard, compact nature, the exterior being different from the interior, owing to the fact that the corrosive agents, the acid and gas, corrode the surface of the buckle first and have to act through that already corroded in order to act upon the lead metal still unaffected. In fact, if you were to cut a buckle in two, just as it is taken from the pot, you would have in the centre the "blue" or metallic lead, and on each side hard, compact layers of corroded lead, somewhat different in texture and color.

The lead is now corroded, at least a certain percentage is, and the next process consists in separating that which is corroded or partially corroded, from the metal, which is done by passing the buckles through rollers or crushers.

The good corrosions are brittle; the poor soft; but in either case they are easily separated from the blue lead, because the latter is so malleable, and are remelted into new buckles. A few small particles of blue lead pass on with the corroded lead, which it is very difficult to remove. Water is either added to the buckles before they are removed from the pots or at the time they are put through the rollers or just after, in order to lessen the amount of dust, which is poisonous if taken into the system by the workmen. In some cases the corroded lead is not moistened until after it comes from the rollers, at which time a considerable quantity of water is added, the corrosions being carried to a water mill, in which they are thoroughly ground; the coarse lead being returned again and again to the eye of the stones, the fine being carried on with water. The consistency as it comes from the water stones is like a thick white pulp, and the process then consists of thoroughly washing and neutralizing any traces of acetate of lead, as well as of taking the coarse lead back to the grinding stones. After the lead is thoroughly washed and settled it is, in the process under consideration, either dried by evaporating the water and sold in a dry state, or ground in linseed oil; or while in the pulp form ground in linseed oil, the lead taking up the oil and a small percentage of the water, the remainder of the latter being siphoned off and the mixture of lead and oil passed through the grinding mills. This lead is termed "pulp" lead, and is inferior to that where the pigment is dried before the oil is added, which is styled "pan-dried" in contrast with "pulp."

As heat is generated when linseed oil is mixed with White Lead, the conclusion is drawn that there is chemical action between the two, and I am of the opinion that the linseed oil is saponified to a certain extent by action of the hydrate or hydroxide in the lead. This is true as regards the product of the Dutch Process or of the "Carter."

The Carter Process employs the same chemical principle as the "Dutch," for that is absolutely necessary, White Lead being made by chemical action as already indicated, but the materials used for

the corrosion of the lead are handled in a more modern way, and the corrosion carried on in a more scientific manner. The idea of using the lead metal in the form of sheets rather than as bullion and in the form of perforated discs or buckles rather than as sheets in order to expose more surface to the corrosive agents, is carried still further, in fact to perfection in the Carter Process by atomizing the lead metal: and again, the idea in using the spent tan in preference to stable litter for the purpose of generating carbon-dioxide is carried to a further degree of perfection by burning coke for that purpose, the gas being thoroughly cleansed and purified.

In the Carter Process the first step is to atomize the pig lead or bullion, as it is received from the refining works, which is done by melting the lead in a large kettle, allowing it to flow therefrom through proper apparatus in conjunction with superheated steam at a high pressure, the principle being the same as that in the ordinary nasal or throat spray, the result being a finely divided lead metal: in fact so fine that it will cover the hands when handled as would graphite or plumbage. This finely divided lead metal is charged in proper quantity into slowly revolving cylinders five to seven feet in diameter and eight to twelve feet long. These cylinders revolve continually day and night, and the lead charged therein assumes a position along the cylinder on the side which is turning up, the powdered lead as it reaches a certain height overturning and falling to the bottom of the bottom of the cylinder just as would pulverized sugar.

Into the ends of these cylinders at the centre, the carbon-dioxide is admitted, same being drawn through the purifying chambers by means of an exhaust fan and from under the boilers where it is burned, making steam at the same time. The gas as it enters the corroding cylinders is kept at a uniform temperature, such temperature being that which experience teaches produces the better finished product.

The very dilute acetic acid, more dilute than that used in the Dutch Process, is also sprayed into the corroding cylinders by hand through the end, and in this manner water is also added. In short, the lead is contiually agitated, the entire surface being exposed to the combined and continued action of acetic acid vapors and carbonic acid gas at the same time. An obvious advantage of the Carter Process is the fact that the lead can be examined at any stage of corrosion without interfering with the chemical action.

It will be apparent to any one on consideration that the time necessary for the corrosion would be directly proportionate to the fineness of division of the lead metal, the temperature of the materials and the concentration of the corrosive agents, but it must be borne in mind that as the acid acts upon the excess of lead metal it is freed and again freed to act upon more lead metal, working in a circle, so to speak. It is not necessary that strong acid be used, and further, if this were done, the finished product would be more liable to contain

a larger percentage of lead acetate than where the dilute acid is used.

The temperature in the corroding cylinders is about 140 degrees F. until the lead is corroded, after which it cools off and becomes cold; however not until the lead is corroded does the temperature fall. It must not be construed that in this process the corrosion is perfect, for it does average at least 90%, and the remainder is uncorroded, which is readily separated from the corroded lead.

The lead metal is charged into the cylinder as amorphous powder, varying in color from a dark blue to a steel gray and continues during the process of corrosion as a powder and finisher as such. It is then moistened considerably with water and by the revolving of the cylinder allowed to form into balls varying from the size of buckshot to a hazelnut. This is done to prevent the dust which would rise if the product was handled in the dry state.

The lead as taken from the corroding cylinders is carried to the washing machine which consist of rapidly revolving pronged shafts in a cylinder into which the lead is put and a large quantity of water added. The water holds the lead in suspension flowing from the machine and into a series of revolving sieves covered with fine wire cloth of seventy-two meshes to the inch. That which passes through the wire cloth flows on into the first of a series of tubs. The lead left on the sieves is used for making a color that is red in color. Any large pieces of metallic material or ore remaining on the sieves are discarded.

That which passes through the sieves and on to the first of a series of tubs as stated is allowed to settle from one tub into another and more or less constantly agitated, more water being added and by this process all impurity washed out. It is then pumped to settling tanks by means of pumps for that purpose, using a centrifugal pump rather than the ordinary plunger or force pump. After the lead settles in the settling tanks the water is drawn off and the lead allowed to run into copper lined drying pans where the water that is contained is evaporated. After the lead is thoroughly dried it is placed in barrels or kegs, mixed and ground and is then packed, or preserved while in the dry state, packed in barrels and marketed in that form.

The idea in washing, mixing and grinding the lead and oil is to thoroughly incorporate the two together. That manufactured by the Carter Process being more amorphous than the product of the Ball Process, can be more thoroughly incorporated with the oil and will thus take a larger percentage. Lead prepared for the trade is put up in packages kits and kegs and when ready for barrels contains, the ordinary four barrel package, somewhat stronger. White lead is sold to the manufacturers of prepared paints. The dry state that is in barrels they adding thereto zinc white, barytes and various materials, together with more or less oil, as per the grade of paint they make. In fact many paints are put up that contain no lead whatever.

White Lead is used by all first-class manufacturers who have any use for paint, such as the manufacturers of agricultural implements, wagons, buggies: by manufacturers of pottery for the purpose of making the glaze, by manufacturers of enamelware, inlaid linoleums, rubber, etc.

The consumption of White Lead in the United States is between 80,000 and 90,000 tons per annum, and requires for its manufacture a large proportion of the metallic lead produced. The lead metal used by the corroder is the best to be obtained, if he desires the best product, the lead being refined whether it be the product of soft Missouri or silver land ores. In the lead metal, that which gives the most trouble to the corroder is bismuth. Traces of antimony or silver impart a color other than white to the finished product.

Many substitutes as a pigment have been offered from time to time for White Lead, but there is nothing which will beautify and at the same time preserve that to which it is applied as will White Lead, and the characteristics of the good article are its affinity for linseed oil, its opacity and covering properties and its durability as a paint.

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## A WYOMING IRRIGATION SYSTEM.

C. T. JOHNSTON, '95.

In the conservation of its waters, the Laramie river has taken first place among Wyoming streams. The close of the year 1898 will see its entire discharge impounded and held for irrigation.

With the construction of a reservoir having a capacity of 12,000 acre-feet in 1897, the work of storing the flood and surplus water was initiated. In the following year the task will be concluded by the completion of a reservoir capable of retaining 80,000 acre-feet of water. These two storage-works will hold all the water discharged by the river, except the volume used directly from it between May 15th and September 15th.

If the maximum discharge of the stream occurred in July, when the most water is required for irrigation, the demand for storage reservoirs would be less imperative. As it is, however, the floods descend from the snow-fed tributaries in the mountains about May 15th, reach their maximum by May 31st, or June 1st, and then rapidly decline.

### WATER SUPPLY INVESTIGATION.

In promoting the construction of irrigation works having the magnitude of those proposed to be described, it is necessary to first determine the water supply. A thorough study of the quantity available for irrigation is, therefore, a primary step.

The high water of May and June is due to the rapid melting of the snow which falls during the winter months. If the snow-fall has been unusually heavy, or if the temperature is low during the spring, the period of flood discharge may be delayed some weeks. When the waters begin to recede it is evident that the snow has disappeared from the lower mountains. From this time, therefore, until October 1st, the streams suffer from a want of snow. From October 1st to May 15th the low waters are occasioned by a lack of heat to melt such snow as has fallen.

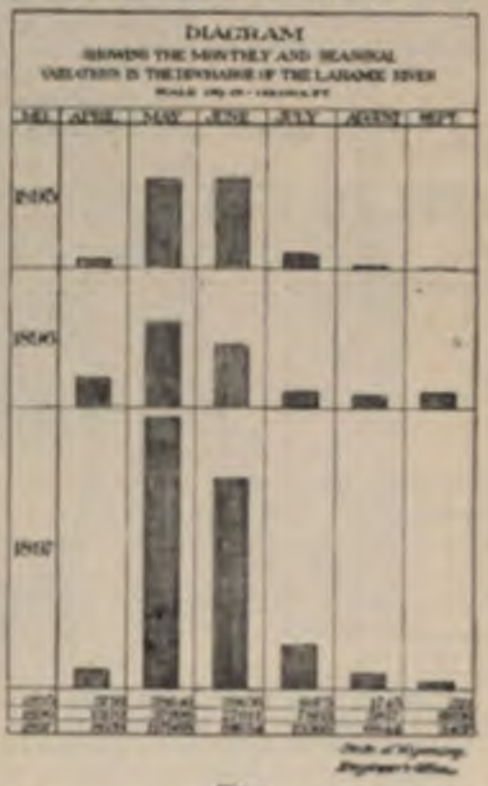


Fig. 5.

Two stream discharge diagrams are shown herewith. One indicates the difference in the discharge of the Laramie river for three consecutive years, and the other shows the fluctuation in the volume flowing during the six months beginning April 1st, 1897.

The rapid rise which occurred from May 3rd to May 12th was probably due to several days of warm weather in the mountains. On the 8th of June the maximum effect of a cold period is shown. The small fluctuations in July and August are due to local storms more than to the condition of the weather in the mountains.

One of the sources of financial loss, resulting from investments in western agricultural enterprises, is in over-estimating the value of land which has an inadequate water-supply. Much capital has been expended in the construction of ditches and other irrigation works only to find, when profit should begin to accrue, that the quantity of water is wholly insufficient to properly irrigate the land. For this reason great care should be taken in preliminary reports that the volume of water proposed to be used be determined and stated precisely.

## THE WYOMING DEVELOPMENT SYSTEM.

The land susceptible of being watered under this system of irrigation lies between Sybille creek and Chugwater creek, in Laramie County. It is an unbroken table land having an area of 60,000 acres. The soil is a sandy loam and very uniform.

This tract of land was the incentive to the irrigation development. Construction began early in the last decade and the details of the distributing works then planned have been steadily improved during the last fifteen or sixteen years.

The first scheme was to build a canal from the mouth of the

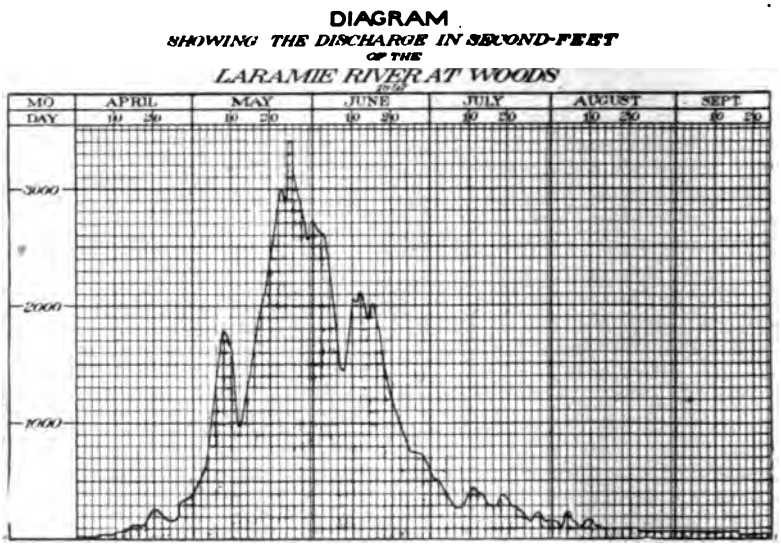


Fig. 4.

Laramie river canon as shown by the dotted survey line on the accompanying map. Where the survey crossed Sybille creek, a flume 70 feet high and one-half mile long was necessary. Added to this expensive structure the canal line failed to cover a large portion of the land. Other means were debated and after several preliminary surveys this project was abandoned.

The most feasible plan which presented itself was to turn water from the Laramie river into Blue Grass creek, a tributary of Sybille creek, and then construct ditches from the latter stream. The alternatives offered for solving this problem were, either to build a canal some fifty miles in length and discharge it into the headwaters of Blue Grass creek, or to make a short, but expensive water-way, between the two streams in the mountains.

W.D.C. IRRIGATION SYSTEM
WYOMING

As shown by the map the streams draining the Laramie mountains run through the range from the high table lands upon which Reservoir No. 2 is situated. The elevation of this plain is 7,000 feet while the land irrigated has an altitude of but 4,500. This geographical feature makes a canal project, as above described, entirely feasible.

However, during one of the exploration surveys, a tributary of Blue Grass Creek was followed towards its source until a point was found which proved to be but slightly over one-half mile from the Laramie river and over fifty feet below the bed of that stream. The intervening mountain being eliminated nothing would interfere with converting Blue Glass Creek into a river.

A tunnel was necessary and as soon as practicable, surveys were made in preparation for actual work.

## THE TUNNEL.

The tunnel is 2,978 feet long, 7 feet high and 8 feet wide. It has a fall of two feet per 100 for the first 400 feet and one foot per 100 throughout the remainder of its length.

The dam and canal were first built and a turbine wheel was installed near the north portal of the tunnel. This wheel furnished power to an air compressor, which in turn, ran drills at both ends of the work. The air was piped for a distance of one mile over the mountain, but with little loss, and the work was carried on without intermission after the plant was erected until the headings met.

The triangulation system which located the center line of the tunnel was rendered difficult by the broken nature of the mountains in that locality. Instead of being able to adopt one well-measured base, five short lines were determined and included in the work. A B is the only line which can rightly be called a base and it was measured only to determine A C. This work was checked by various small systems.

It will be noticed by comparing the plat of the triangulation system and the cross-section of the mountain along the tunnel line that the stations H. J. and K. occur on the highest points of the line.

The rock through which the tunnel was run is a gneiss with sufficient mica in its composition to prevent chipping under the drill. In addition to this difficulty attending the drilling the rock was so tenacious that only the strongest explosives would effect it. The material excavated on the north end of the tunnel was dumped into the river from the cars. On the south end of the work the rock was thrown into the natural channel leading to Blue Grass Creek.

The canal leading from the river to the tunnel is 2,000 feet long. At its head a rock-filled crib dam has been constructed across the river and a substantial timber headgate has been built. This gate is but a box having the width of the canal on the bottom, vertical sides and a length with the canal of 40 feet. The flow of the water is regulated by four vertically sliding gates which are raised by means of a lever from above and fall with their own weight when released.

Water first ran through the tunnel in May, 1886. During the first day the entire mass of rock which had accumulated in the creek at the lower end of the tunnel, disappeared under the action of but 80 cubic feet of water per second. It is estimated that 7,000 tons, or 14,000,000 pounds, of rock, varying in quality from sand, to stones weighing 20 pounds, were carried away.

### CANAL NO. 1.

Canal No. 1 first diminishes the supply of water thus furnished Sybille Creek. It is 34 miles long, 25 feet wide on the bottom and in common with canals No. 2 and No. 3 it has a fall of 2 feet in 5,000 feet and side slopes of 1 to 1. It carrying capacity is 428 cubic feet per second.

The headgate is similar to that on the tunnel canal. The dam at the headgate is a framed structure, built on piles.

In the first ten miles three flumes, supported each 12 feet by piles, were constructed. These crossed streams which are normally dry, or nearly so, but being subject to floods ample provision had to be made for water-way. Driftwood caused considerable trouble and resulted in the flumes being carried away one or more times. The first one along the line crossing Dead Head Creek was replaced in 1894 by a flume suspended on two Howe trusses having a span of 70 feet. This substitute does not encroach on the channel of the stream and has withstood the high water for four years. The tension members can be tightened as necessity demands.

At Brush Creek, the short span flumes have been superceded by three wooden pipes each four feet in diameter. These pipes are 275 feet long and have a fall of 10 inches in that distance, and are laid from 4 to 6 feet underground.

At Sand creek a similar substitute for a flume has been put in. The pipes are of the same diameter and number. They are 300 feet long and have a fall of one foot in that distance. This has proven a simple and economical method for carrying water across ravines or wherever ditch construction is difficult.

The remainder of the canal is an open cut. Laterals depart from it as is demanded in the irrigation of the land lying below.

### CANAL NO. 3.

This canal was built primarily to fill Reservoir No. 1. It is 15 feet wide on the bottom, five feet deep and is but eight miles long. Its carrying capacity is nearly 214 cubic feet per second.

Its most interesting feature is the wooden pipe conveying its waters under Brush creek. This is but a single pipe, 4 feet in diameter, 400 feet long, and having a fall of one foot in that length.

These pipes are called "inverted syphons" and are protected from being choked by floating material by vertical timbers placed a few inches apart across the penstock.

## CANAL NO. 2

Canal No. 2 was built to irrigate the north one-third of the land. It is 22 miles long, 30 feet wide on the bottom, 5 feet deep, and has a capacity for 300 cubic feet per second. The country through which it is excavated is an unbroken mesa and in the entire 22 miles there is no occasion for a flume or syphon.

## THE RESERVOIRS RESERVOIR NO. 1

Reservoir No. 1 is supplied by canal No. 3 directly and canal No. 1 through its lateral No. 1.

The site is a natural basin covering an area of 600 acres. But few localities offer a better opportunity for storing water. No embankment was necessary. A means for drawing off the water as it is needed was all that the completion of the work required.

The outlet is 2,000 feet long. It begins on the reservoir side with a cut 400 feet in length and varying from 0 to 25 feet in depth. A stone arch 20 feet long, 4 feet wide and 4 feet high to the crown leads from this where two riveted steel pipes 2 feet in diameter and protected from the pressure of the earth by concrete, run 60 feet farther to the valves.

The valves are worked from the surface 30 feet above and are easily manipulated.

From the valves the water is carried for 10 feet by similar steel pipes where it runs through two lines of vitrified pipe of the same diameter 600 feet to the lower cut, which begins with a depth of 25 feet and runs 1,000 feet to grade. Here two ditches divert the water. One follows the contour of the country on a grade of .3 in 1,000 and the other acts as a feeder to canal No. 2.

## RESERVOIR NO. 2

The reservoir is on the Laramie Plains. It is 10 miles long and from a few hundred feet to a mile and one half broad. The depth varies from 15 to 40 feet.

The work necessary for its completion consists of an embankment one mile long extending across the valley of the river. It varies from 5 to 30 feet in height.

In the river channel six inclined gates will be placed and these will be supported by masonry walls sliding in iron grooves. They are to be operated from above by a rack and pinion device. The rack is to be bolted to the under side of the gate and the shaft containing the pinion is to be worked by a hand wheel having a diameter of four feet. By means of a ratchet wheel on the shaft the gate can be held in any desired position.

At the northern extremity of the reservoir is a rock ledge over a low place in which the surplus water can return to the river channel.

# ARMATURE REACTIONS AS RELATED TO ELECTRICAL DESIGN.

FRANK C. WAGNER, '85.

The systematic treatment of the design of electric generators and motors may be said to have had its beginning in the celebrated paper of Drs. J. and E. Hopkinson, communicated to the Royal Society of London in April, 1886. The method pursued by the authors was to select a dynamo whose dimensions and winding were definitely known, and to calculate what should be the output in volts and amperes at a given speed. Experiments were then made with the dynamo and the actual output was compared with the calculated value. In this paper the effect of the armature reaction is allowed for in the calculation.

The manner in which the armature reaction limits the output of a dynamo or motor, and its relation to destructive sparking were first clearly presented from a theoretical standpoint by Mr. J. Swinburne (*London Electrical Review*, Feb. 14 and 21, 1890), and at about the same time on its practical or empirical side by Mr. W. B. Esson (*London Electrical Review*, Feb. 28, 1890). The papers of Swinburne and Esson with their empirical formulæ have furnished the standard treatment of this subject, as given in text-books, up to the present time.

During the past year and a half renewed interest has been shown in the subject of armature reactions, especially in Germany, and important contributions have been made in the direction of more complete treatment, and of application to modern types of machines. Special attention should be directed to the papers by Mr. J. Fischer-Hinnen published in the *Electrotechnische Zeitschrift*, September 17 and 24, 1896, and October 14, 1897. The first paper has been translated and published in the *Electrical World*, March 20, 27 and April 3, 1897.

Most of the text-books upon electrical design treat the subject in the order of the historical development of the theory instead of according to the logic of the design. Certain data must always be given by the problem itself, such as the electro-motive force at the terminals, the output, the number of revolutions per minute, and the type of machine, i. e., whether bipolar or multipolar, continuous current or alternating current.

The first thing to be determined is the diameter and length of the armature core. This evidently depends upon the number and size of the conductors to be used. The size of each conductor is readily determined by the allowable current density, which depends upon the heating limit. It is common in the ordinary text-book treatment to assume also the number of conductors on the armature, relying upon the experience obtained by other designers of similar machines.

Consequently this portion of the design is purely empirical and there is nothing to guide the designer when the problem presented is outside of the range of ordinary practice. Fortunately, the material for a theoretical treatment of the subject is at hand, and in what follows an attempt will be made to put it into shape useful to the designer, and especially to the beginner in electrical design.

The *number* of conductors on an armature is limited by the tendency to produce sparking in continuous current machines, and by the self-induction and the distortion of the air-gap induction in alternating current machines.

In continuous current dynamos and motors the connections of each armature coil must be reversed at or near the point in the revolution of the armature where the electromotive force generated in the coil considered is reversed in direction.

When the connections of an armature coil are reversed the action of the brushes upon the commutator is first to short circuit the coil and then to connect it with the other coils in such a way that the current traverses it in the opposite direction. The effect of short circuiting a coil in a position where no electromotive force is being generated in it is as follows. The current previously flowing in the coil tends to diminish and would quickly become zero if left to itself. The induction through the armature due to the current in the short circuited coil also diminishes, and in so doing changes the total induction passing through the coil. As the result of this action an electromotive force is generated in the coil in a direction which tends to maintain the current existing before commutation and to oppose the current existing after commutation. Under the action of this electromotive force a current is actually maintained in the short-circuited coil for a length of time depending upon the resistance and the self-induction of the coil. If this current has not become zero by the time the short circuit is broken, then its sudden stoppage will give rise to an electromotive force opposing the current which is to circulate in the coil after commutation.

In a similar manner the change of induction due to the new current produces a counter electromotive force in the coil. The remainder of the armature winding furnishes an electromotive force to the coil equal to the sum of these two opposing electromotive forces, and as a result there exists for an instant between the two adjacent commutator bars a very considerable electromotive force which drives a current through the air gap when the brush leaves the retreating segment. This is the *sparking* which is observed in all continuous current dynamos when the brushes are not properly set.

If, instead of commutating the coil in a position where the induced electromotive force is zero, the position of the coil during commutation be such that an electromotive force is being generated in it in an opposite direction to that which tends to produce sparking, then the sparking may be entirely prevented.

Let the current flowing normally in a single armature coil be represented by $I_1$, the resistance of the coil by R, the coefficient of self-induction by L. Let $I'_1$ be the current flowing at a time T after the establishment of the short circuit. Then $I_1' = I_1 e^{-\frac{RT}{L}}$ (1). Similarly, if $E_1$ equals $I_1 R$, then $E'_1 = E_1 e^{-\frac{RT}{L}}$ (2). This is upon the supposition that no other electromotive force is acting in the coil.

If the coil which is being commutated moves through a field,--supposed to be uniform for the distance the coil remains short circuited,--which tends to produce an electromotive power equal to $E_2$, then, in a similar manner, the instantaneous value of the electromotive force due to this cause is $E'_2 = E_2\left(1-e^{-\frac{RT}{L}}\right)$ (3). This electromotive force should be opposed to the electro-motive force of self-induction. The actual current flowing at any time T during the short circuit will be that due to the resultant of these two electromotive forces, or $I = I'_1 - I'_2 = \frac{E'_1 - E'_2}{R}$ (4).

In order that the commutation may be sparkless, the electromotive force produced by the field during the period of the short circuit should be sufficient, not only to reduce the currents in the coil to zero, but also to establish a new current in the opposite direction exactly equal to that which the coil is to carry after the commutation is completed. That is, $E'_1 - E'_2 = -E_1$. Or, $E_1 e^{-\frac{RT}{L}} - E_2\left(1 - e^{-\frac{RT}{L}}\right) = -E_1$ (5).

$$\therefore \quad \frac{E_2}{E_1} = \frac{\left(1 + e^{\frac{TR}{L}}\right)}{\left(e^{\frac{RT}{L}} - 1\right)} \quad (6).$$

In any particular case the value of R may be determined by assuming the percentage of the voltage to be lost in the armature Let $f$ be this percentage expressed as a fraction, E the electromotive force at the terminals, J the total armature current, K the number of parallel paths through the armature winding, and $N_1$ the number of coils on the armature. Then the entire resistance of the armature is $\frac{f E}{J}$, and the resistance of each coil is $R = \frac{f E K^2}{J N_1}$ (7).

T in equation (6) is the time during which a coil is short circuited. If $\gamma$ represent the width of brush contact surface minus the insulation between two commutator segments, $D_1$ the diameter of the commutator, and $n$ the number of revolutions per minute, then $T = \frac{60\,\gamma}{\pi D_1 n}$ (8).

The value of L depends upon the style of armature core used.

Mr. J. Fischer-Hinnen in one of the papers referred to above, makes approximate calculations of L for several cases of drum wound armatures obtaining the following results:

For a slotted armature in which the width of the teeth is $\frac{1}{2}$ times the width of the slot and the depth of slot is three times its width, $L = \frac{2 \cdot 1 \cdot N_c^2}{10^8} \cdot l$, where $l$ is the length of the armature core in centimetres and $N_c$ is the number of conductors in one coil.

For half closed teeth of the usual proportions, $L = \frac{1 \cdot 1 \cdot N_c^2}{10^8} \cdot l$.

For toothed armatures, $L = \frac{0 \cdot 5 \cdot 1 \cdot N_c^2}{10^8} \cdot l$.

For smooth core armatures, $L = \frac{0 \cdot 2 \cdot 1 \cdot N_c}{10^8} \cdot l$.

If $\alpha_i$ represent the variable coefficient in the value of L, then $W_i = \alpha_i \cdot K \cdot \frac{10^8}{N^2} \cdot \frac{I^2}{D \cdot n \cdot l \cdot (N_c)^2}$.

If K corresponds to the number of poles as is commonly the case, and $\alpha_i$ is the fractional part of the entire circumference that is covered by one pole face, B the intensity of induction in the air gap and D the diameter of the armature core, then $E = \frac{\alpha_i \cdot N \cdot N_c \cdot n \cdot D \cdot l \cdot B}{60 \cdot 10^8 \cdot K} \cdot 10^{-8}$.

Of these quantities K depends upon the type of winding and must be a number assumed in advance. It can be taken as between 2 and 6 depending on the size of the machine. $D_c$ depends upon the number of commutator bars and the circumferential width covered by one brush. $\alpha_i$ depends upon the type of machine and can be assumed at the outset. B can be assumed as between 3000 and 5000. I is given by the problem. l depends upon the type of armature core and can be taken as given above. All the quantities in equation 15 are therefore either known in advance or may be assumed independently of the remainder of the design with the exception of D the diameter of the armature, and $N_c$ the number of conductors in one coil.

The values of N and D depend upon the total number of conductors on the armature, which in turn is limited by the cross magnetizing effect of the armature in a manner to be described presently and which also depends upon the fundamental formula for the generation of electromotive force, viz. $E = \frac{\alpha \cdot n \cdot D \cdot l \cdot B}{60 \cdot 2 \cdot p \cdot 10^8} \cdot N$, where N is the total number of conductors on the armature and $2p$ is the number of poles. Evidently $N = N_c \cdot N_s$.

After D and N have been determined the value of $\frac{W_i}{l}$ and the

calculated from equation (15), and the corresponding value of $\frac{E_2}{E_1}$ by equation (6) or by the following table:

| $\frac{R T}{L}$ | $\frac{E_2}{E_1}$ |
|---|---|
| 4.6 | 1.01 |
| 3.7 | 1.05 |
| 3.04 | 1.1 |
| 2.4 | 1.2 |
| 1.78 | 1.4 |
| 1.46 | 1.6 |
| 1.1 | 2.0 |
| .85 | 2.5 |
| .69 | 3.0 |
| .52 | 4.0 |
| .405 | 5.0 |
| .198 | 10.0 |
| .11 | 20.0 |

The current normally flowing in one armature coil equals $\frac{J}{K}$. Hence $E_1 = \frac{J}{K} \times R = \frac{f E K}{N_1}$ (17). From this the value of $E_2$ is readily found.

Now $E_2$ is the electromotive force which must be generated in the coil while it is being commutated. It remains to determine the intensity of induction needed to generate this electromotive force. Let the intensity of the induction which is being cut by a coil during commutation be represented by $B_2$. Then $E_2 = \frac{\pi D n N_2 B_2 l}{60 \times 10^8}$ (18).

Hence $B_2 = \frac{E_2 \times 60 \times 10^8}{\pi D n N_2 l}$ (19).

It is evident that, if $B_2$ be greater than can be obtained in the interpolar space, no position can be found for the brushes which will obviate sparking. In such case a different value must be taken for $N_2$. What is the maximum value of $B_2$ allowable? This depends upon the effect of the armature reaction in the following manner.

The magnetizing effect of the armature conductors may be separated into two parts, that which changes the total induction passing from one pole piece through the air gaps and armature core to the other, and that which simply changes the distribution of the induction over each pole face.

Of the conductors on an armature those lying outside of the angle of the pole faces serve only to increase or diminish the total induction from pole to pole. If the plane of commutation is the medial plane, then the conductors on one side tend to increase the effective induction and those on the other side tend to diminish it.

The resultant effect is zero. If the plane of commutation be shifted forward in the direction of rotation, then the demagnetizing conductors exceed the magnetizing, and the resultant effect is to diminish the total induction from pole to pole. This is the case in all dynamos. If the plane of commutation be shifted backward, then the magnetizing conductors exceed the demagnetizing, and the resultant effect is to increase the total induction from pole to pole. This is the case in motors.

The conductors lying within the pole face angle produce inductions which pass across the air gap on one side of the conductor, through the metal of the pole and back across the air gap on the other side. Since the inductions pass in both directions through the same air gap, the total induction through this air gap will not be changed, but its distribution over the pole face will be altered. An inspection of the paths of the induction shows that at the center of the pole face the resultant magnetomotive force due to the armature conductors is zero, because the conductors on either side act oppositely. As the distance from the center increases, the number of cross magnetizing conductors becomes increasingly greater on one side than on the other. At the edge the magnetomotive force is that due to all the conductors included within the polar angle. Since the magnetomotive force due to the armature conductors is in opposite directions across the air gap at the two edges of the pole face, its effect is to increase the intensity of induction at one edge and to diminish it at the other edge. Since the plane of commutation is always shifted toward the pole tip where the induction is weakened, it becomes a matter of importance to determine what the resultant intensity of induction at the weakened pole tip is.

Let C equal the total number of conductors on the armature; $i$ the current through each conductor; and $\phi$ the polar angle in degrees. Then the magnetomotive force at the edge of the pole face due to the armature cross magnetizing conductors is $\frac{4\pi Ci\phi}{10\times 360}$ for the entire circuit. Since the magnetomotive force acts over two air gaps, one-half will be applied at each edge, the reluctance of the iron parts of the circuit being neglected, and will be $\frac{\pi Ci\phi}{5\times 360}$.

If the intensity of induction due to the field magnets be represented by B, and the length of the air gap in centimeters by $l_g$, then the magnetomotive force across the air gap due to the field magnets is $Bl_g$. In order that there may be sparkless commutation, therefore, $\frac{\pi Ci\phi}{5\times 360}$ must be less than $Bl_g$. Just how much less depends upon the strength of field required to produce sparkless commutation, i. e., upon the value of B.

Practical experience has shown that with the ordinary forms of dynamos and motors the value of $\frac{\pi Ci\phi}{5\times 360}$ should not exceed $\frac{1}{4}Bl_g$ for

drum armatures, or $\frac{1}{2} B l_0$ for ring armatures. Hence the limiting values of the armature ampere terms are given by the following equations:

For drum armatures, $Ci = \frac{382}{\Psi} B l_0$ (20).

For ring armatures, $Ci = \frac{286}{\Psi} B l_0$ (21.)

It is to be observed that equations (20 and (21) take no account of the self induction of the armature coils. They may be used to obtain a first approximation to the allowable number of conductors on the armature, but the final calculation, and also the division into coils should be made by reference to equations (6), (15), and (19).

Attention should also be directed to the advantage of multipolar machines over bipolar as shown by equations (20) and (21). The maximum ampere turns is inversely as the polar angle, that is, directly as the number of poles, if the value of B and $l_0$ be fixed.

Various devices have been suggested to overcome the evils of sparking, the most important of which are the Sayers winding, developed in England, and the Ryan device, which has been brought out in this country. However, by the use of multipolar machines for large capacities satisfactory results are obtained, so that such devices have not the importance they would otherwise have had.

By the use of the foregoing analysis and formulæ, the maximum total number of conductors on the armature, and also the maximum number of conductors in one coil can be determined. If it is possible to secure a suitably proportioned armature with a less number of conductors, so much the better. But the maximum values obtained must not be exceeded.

To illustrate, let it be required to design a 200-kilowatt dynamo to give 100 volts at 300 revolutions per minute.

If a bipolar dynamo of the closed coil type be adopted, then one-half of the entire current will flow through each conductor, and $i$ equals $\frac{200000}{100 \times 2} = 1000$ amperes. If $\Psi = 130$ degrees, and B = 6000, then $1000\ C = \frac{382}{130} \times 6000\ l_0$; whence $C = 17.6\ l_0$. Let the armature be slotted. Then $l_0$ might be made only just large enough to give mechanical clearance, or 0.4 centimeter, whence C = 7; i. e., the number of armature conductors cannot exceed 7. Evidently this is not sufficient to give a good construction of commutator. If C be taken as 64, giving a commutator of 32 segments, then $l_0$ = 3.6 centimeters or 1.42 inches.

With a current density of 3000 amperes per square inch, the cross section of each conductor is $\frac{1}{3}$ square inch, or 1 inch by $\frac{1}{3}$ inch. If $\frac{1}{8}$ inch be allowed for the circumferential width of each conductor and and its insulation, and $\frac{9}{16}$ inch for the iron between slots, then the diameter of the armature becomes $64 \times 1\frac{1}{8} \div \frac{22}{7} = 19$ inches, or 48 centimeters.

To generate 100 volts the length of the armature core must be obtained from the formula, $E = \frac{a\ C\ \frac{11}{7}\ \pi\ D\ l \times 6000}{60 \times 10^8}$; whence $l = \frac{10^8}{300 \times 64 \times \frac{11}{7} \times \sqrt{7} \times 48} = 95.4$ centimeters or 37.5 inches.

In order to determine the strength of field needed for sparkless commutation, substitute in equations (17), (13) and (19). Let $f$ equal .02; $K = 2$; $N_1 = 32$. $\therefore E_1 = \frac{.02 \times 100 \times 2}{32} = .12$ volts. $\frac{7}{\pi D_1} = .05$ $\therefore \frac{H\ T}{L} = \frac{.02 \times 100 \times 4 \times 60 \times .05 \times 10^8}{300 \times 32 \times 300 \times 2.3 \times 95.4 \times 4} = 0.143$. From equation (6) above the value of $\frac{E_2}{E_1}$ corresponding to this value of $\frac{H\ T}{L}$ is 14. $\therefore E_2 = 14 \times .12 = 1.68$, and $B_1 = \frac{1.68 \times 60 \times 10^8}{\sqrt{7} \times 48 \times 300 \times 2 \times 95.4} = 1168$.

Since in the derivation of equation (20) the back magnetomotive force at the edge of the pole face due to the armature current was taken as $\frac{1}{4}$ of that due to the field magnets, the actual magetomotive force remaining is $2000\ I_a$. The magnetomotive force over the air gap at the adjacent edge of the other pole, being increased by the cross magnetizing effect of the armature current, is $6000\ I_a$ plus $4000\ I_a = 10000\ I_a$. The plane where the indensity of induction is 1168 can be found by the approximate formula, $\frac{2000\ I_a}{\pi\ (c-a)} \quad \frac{10000\ I_a}{\pi\ (c+a)} = 1168$; in which $a$ is the linear distance from the position of a coil during commutation to the medial plane of the machine, and $c$ is the distance of the edge of pole face from the medial plane. $I_a = 3.6$ centimeters; $c = 12.7$ centimeters. Hence $a = 11.3$ centimeters. That is, the plane of commutation is 12.7 minus 11.3, equal to 1.4 centimeters or 0.55 inch, away from the pole tip. Stated differently, the angle through which the brushes must be shifted from the medial plane is .89 of the distance to the pole tip.

Mr. Fischer-Hinnen found that in practice when the angle through which the brushes are shifted is more than .75 of the distance to the pole tip, the machine is apt to spark badly. Consequently, although the assumed data satisfy equations (16) and (20), which are the conditions ordinarily specified in the text-books, yet the dynamo would not operate satisfactorily. The remedy is either to increase $I_a$, which is already too large for economical field coils, or, what is much better, to adopt the multipolar type of machine.

## NOTES ON RAILROAD BRIDGE CONSTRUCTION.*

HENRY GOLDMARK, A. B.

The railroad system of the United States constitutes at the present day more than half the total railway mileage of the world. As a machine for the economical transportation of freight, it is unrivalled elsewhere, as the rate per ton-mile is very much lower than in any other part of the world. The economic importance of this fact need not here be enlarged upon. It has been brought about mainly by the great improvements in engines and rolling stock made during the past twenty years.

There has also been much improvement in the roadbed, track and bridges, but it does not seem to me that the advance has been proportionally great in this direction. Certainly a large part of our railroad track and structures does not compare favorably with the average in other countries. With the exception of certain trunk lines, of high excellence, most of our roads still show in their narrow embankments and cuts, their poor drainage, their insufficient ballasting and the large amount of timber trestling, the economic pressure for immediate results under which they were built. In saying this, I do not forget, that in many cases, these were good and sufficient reasons for economy, and that the opening up of our vast territory would have been impossible without much work that lacks permanence.

At the present time, when few new lines or extensions are under way or projected, the improvement of existing roads may probably engage our attention.

In my remarks this evening, I mean to confine myself to one phase only of railroad improvement, although an important one, that of bridge structures. I intend to dwell particularly upon certain practical considerations that should govern in the design and construction of the ordinary railroad bridge, rather than to discuss the determinations of strains, or the details of shop work.

By "ordinary" railroad bridges are meant spans of moderate length, say up to 150 or 175 feet, over which trains usually pass at full speed. The great majority of all railroad bridges belong to this class.

The design of long spans over wide rivers is in many respects an entirely different problem and is to a great extent independent of conditions prevailing on the rest of the line. The location of such bridges can often be made to depend wholly on the hydraulic and topographical conditions since they are of sufficient importance to influence the alignment of the road or to call for the building of special approaches. In their construction, the dictates of theoretical economy can often be closely followed.

*Abstract of paper read before the Engineering Society.

The shorter bridges, on the other hand, are merely a part of the roadbed, and their construction should be governed entirely by traffic requirements. It should always be borne in mind that a bridge of this kind, is in no sense, a monument or thing of beauty, which is an end in itself. However interesting it may be to us as a piece of construction, its doing, its necessity at a given point must be fully established and its construction must merely be such as to ensure the required work in as efficient a manner as possible.

Considered as a part of the roadbed, any bridge or cattleguard, is objectionable.

In the first place, except in the case of temporary trestling or high viaducts, its first cost is always much greater than that of an equivalent length of embankment or excavation. In the second place the cost of inspecting and keeping in repair wooden and metallic bridges is always considerable, while the ordinary roadbed involves little expense for maintenance.

Last but not least.—Every additional bridge or cattleguard increases the care and responsibility of keeping the track in a proper condition for the safe and easy passage of trains. In case of a derailed truck or of even slight injury to the rolling stock, the chances of a serious accident are much increased by the break in the roadbed, involved in the presence of a bridge. For this reason, any structure removed from the line, lightens pro-tanto, the load of responsibility which rests on the shoulders of the officials directly charged with the operation of the road and improvements of this kind are gladly welcomed by them.

Competent locating engineers, as a rule, appreciate the considerations just mentioned, although, I believe, that in many cases, a more detailed knowledge of bridge superstructure, would show them how to reduce the total amount of bridge work without either increasing the length of the line or changing it for the worse in respect to gradients or curvature.

At best, however, with the conditions under which locations must usually be made, mistakes in the number, the length and the character of the bridges, will be unavoidable, which will be apparent in the light of later experience. There is often little chance to ascertain the nature of the streams crossed nor the extent and character of their watersheds. Even flood discharges and high water levels must often be guessed at, from the unreliable statements of "old residents." Hence, ordinary prudence generally leads to the use of rather excessive waterways although in other cases the spans prove to be too small, while an enforced economy of time and money introduces much timber trestling not called for by hydraulic considerations. In place of masonry abutments, framed piers of timber, sometimes filled with loose stone, are often used as a temporary supports for iron or timber spans. This practice of not building the masonry structures until later has much to recommend it, as it

avoids the necessity of using stone from untried quarries, which may not stand the weather. On some roads the temporary timber piers and trestling are placed in such a position as to leave a clear space for building the masonry afterwards. Foresight of this kind frequently saves time and money.

**Arches and Culverts**—As to the character of the permanent structures, those that approximate most closely to the unbroken roadbed, are the best from the operating standpoint. I refer, of course, to the covered culverts or arched bridges. Their use for small spans, is quite common; for large streams, arches are little used on account of their greater first cost. If the expense of maintaining and replacing less durable work, were taken into account, the ultimate economy of the arch might often be made plain.

In case there is little water, one or more square box culverts, covered with stone slabs are the cheapest and best outlet for drainage. Where stone is scarce, cast-iron pipes may be substituted up to a diameter of 6′ or even more. Their use has been entirely satisfactory. Tile drains are cheaper and easier to lay, but are very easily broken under traffic, and expensive to replace.

Culverts of circular section up to 8′ or more in diameter and built entirely of cement have also been used on some western roads. On the new water supply system for the city of Boston, now under construction, many miles of such conduits are being built of concrete instead of brick. Their use on railway work is likely to be more common in the future. The wooden molds can be used many times in different places and improved methods of mixing and ramming the concrete can be employed where there is much work of the kind to be done. Portable machinery would ensure a more homogeneous mixture than can be obtained by hand work.

It seems to the writer a mistake to insist on the use of Portland cement in all cases. The native Natural Cements cost less than one-third to one-quarter as much and if used in somewhat more generous proportions, give a sufficiently strong product at much less expense.

**Repairs of Masonry.**—A further use of cement mortar may here be referred to, namely its application to the repair of masonry structures disintegrated by the weather. For this purpose, a very strong dry mixture with the best Portland cement must be used and if possible, mixed by machine. The masonry must be thoroughly cleaned, loose pieces removed and the joints raked out to a depth of several inches. A wooden mold is placed, so as to leave an intervening space of from 4″ to 10″ between the lagging and the old surface of the masonry. This interval is filled with the cement mortar or beton, which is thoroughly rammed into all crevices and joints. In this way, an entirely new surface is put over the old work, which is protected from the weather and more firmly united. I have had occasion within a year or two to examine carefully some repairs of this kind made on

the Erie railway nearly 20 years ago. The surface of the cement mortar was found to be absolutely perfect and free from cracks. It was very hard and showed plainly the shapes and joints of the timber lagging used in the molds.—The structures thus repaired comprised a large number of arch culverts and bridge piers. The method was described by Mr. O. Chanute the Chief Engineer of the railroad in a paper read before the American Society of Civil Engineers in 1880. The original masonry was, in many cases, in the last stage of decrepitude, while at present, after 20 years service the culverts and piers, so protected are entirely sound and promise to last a long time. The cost of such repairs, is only a small percentage of what new masonry would cost, particularly, where a culvert is built under a high embankment, making the expense of excavating it very great.

The selection of durable building stone is by no means easy. Mineralogical study may be of some assistance though the test of actual use is the only certain guide. In many localities, such as Chicago, no reliable local stone can be found, and the nearest available quarries are fully 150 miles away, so that the freight rate adds nearly $1.50 to the cost of each cubic yard. In such localities the use of hard burned brick and concrete would give a good reliable substitute for stone. Brickwork is thus used in the northern part of Germany and in Holland, almost to the exclusion of stone.

In most bridge piers and abutments, as well as in arches, great compressive strength and hardness are not essential in the stone used, as the stresses developed are small. Soft sandstones can often be found which can be cheaply worked, and weather perfectly. The cost of cutting them is $2 to $3 cheaper per cubic yard than for the harder limestones.

The cost of masonry may also be reduced by omitting all copings, ornaments and unnecessary cutting, and by using concrete or rubble for backing. In fact, if carefully built with good cement mortar, rubble masonry is a very good substitute for cut-stone, and is too little used for ordinary rail road work. It is the standard construction for the best built German railroad lines, where the art of making a good quality of masonry with cheap materials has reached a high stage of perfection. The bad reputation which rubble masonry has obtained in the United States is due largely to the poor shiftless work palmed off on railroad companies under this name.

**Foundations.**—For that portion of the work which is below ground rubble or concrete should generally be used. In wet pits or in localities where it is dangerous to the track to keep an excavation open for any great length of time, the use of concrete permits the filling in of the foundation in a shorter space of time than the employment of any other material.

The foundation for arch culverts should of course be especially unyielding. Where the bed rock does not come to the surface, piles are generally used, though they are not very desirable, unless

the amount of material in the abutments is sufficiently great to make the resultant pressure on the foundation nearly vertical. Where the bedrock is only from 6 to 10 feet below the ground, the choice of the best method of foundation becomes difficult. Piles are rather short under these conditions and are likely to yield sideways, if the soil is at all soft. I can recall several instances in which short piles driven in a soft bottom caused the failure of well built bridge abutments reared upon them.

A method of foundation used by the speaker in a similar situation may be of interest. The structure to be supported was an eight-foot culvert for a double track railroad under an embankment about 20 feet high. There was a firm soap stone at a depth of 9′ below the ground, overlaid by a soft wet clay. The building of a concrete footing would have doubled the cost of the culvert. For this reason, it was decided to use instead of concrete, a bed of crushed rock resting on the soapstone.

The material used consisted of crushed tailings from a zinc mine, the size of the separate pieces varying from 2½ inches to that of a pea. The pit was excavated to the bed rock and the crushed ballast shovelled directly into it from a car standing on a trestle immediately above, so that the fall of 20 feet or so caused the filling to become well compacted. Water from a hose was used to wet it down and cause it to settle more closely.

This foundation presented much the same appearance as a good natural bed of gravel and has proved entirely satisfactory. Its cost was about one-fifth of that of a concrete or masonry foundation.

A somewhat novel substitute for timber piles may also be mentioned here which has recently been used by Mr. H. W. Parkhurst engineer of bridges, on the Illinois Central Railroad in places where an ordinary pile foundation would come above the line of permanent ground water.

The method employed consists simply in driving piles, spaced as usual, but withdrawing each pile as soon as it is driven and filling up the hole with concrete. All the stone piles are then covered with a thick bed of concrete on which the masonry pier is built. The advantage of reaching hard bottom is thus obtained at a moderate cost.

**Trestles.**—The timber trestles on American railroads have a greater aggregate length than all other forms of bridging.

Certain designs differing only in details, have become standard. They are undoubtedly of ample strength even under heavy traffic, and in fact are often stronger than the iron bridges on the same line. They are always subject to great danger from fire, and some of our worst railroad accidents have been due to the burning of trestles. Even when well built, they are hard to keep in good alignment and grade and need many minor repairs from time to time. For this reason, they occupy much of the bridge superintendent's time and atten-

[illegible] a great part of his appropriation. The desirability of replacing trestles by some more durable construction should always be borne in mind. This will usually involve the preparation of comparative plans and cost estimates by the Engineering Department. In many trestles timber trestles are removed several times when a stream is to be filled solid to rebuild in stone or steel. A valuable improvement in trestle floors has lately been made by using a ballasted floor instead of the track laid on ties as in the ordinary treatment. In this case a continuous timber floor is laid on the tops of the bents and the ballast, consisting of broken stone or gravel, is then

The chief necessity against the first and for the adoption of the second construction for the long trestles of the Louisville & Nashville Railroad is the fact that the Louisville & Nashville Railroad and other Southern lines

**Wooden Bridges.** Wooden bridges are gradually going out of use, but they have given excellent service in the past. At present where the cost of steel spans is but little greater and the latter are

[illegible] Many of the Western railroad bridges are built of timber and are [illegible]. A large number of different types were introduced [illegible] and practically all these types, in favor of those which [illegible] the best of mechanical principles. With most of the [illegible] the [illegible] and common sense. The arch bridge is there [illegible] which [illegible]

[illegible] have more or less undoubtedly come from the [illegible] various localities [illegible] have not [illegible] are [illegible] have been [illegible] the [illegible] [illegible] [illegible]

these officials have, in the past, quite generally divested themselves of their responsibility in the matter, by depending on bridge building firms for both designs and construction.

Notwithstanding the high standing of our large bridge building companies, there are many strong reasons, why it is unwise for railroads to entrust them with the preparation of plans instead of merely the execution of designs worked out by engineers in the direct employ of the railroads.

It would lead too far to give these reasons in full; it will be sufficient to point out the fact, that in all competitive designs, the first cost in the shops will be sure to cut altogether too great a figure, instead of the much more important considerations of permanence and rigidity.

The experience of examining many existing bridges in different parts of the country built under various conditions, has convinced me that the competitive system is certain to give unsatisfactory results.

In selecting the type of bridge to be used for such spans as commonly occur on railroads, the necessity for rigidity must always be borne in mind, and a stiff construction selected, even if it is more expensive, than some other design of equal static strength.

From this standpoint pin connections, while an excellent detail for long spans, are very poor for the majority of railroad bridges, especially in case eyebars are used for tension members.

Recent practice favors plate and riveted lattice girders up to lengths of 125 to 150 feet. There can be little doubt that they are likely to supplant all other forms except for very long spans.

Some engineers are much troubled by the fact that the stress determinations in plate and lattice girders are apparently more complex than in pin bridges. In fact for a long time our specifications prescribed a lower unit stress in plate girders than in any other type, although the test of experience was all the time loudly proclaiming their greater strength. Many well designed plate girders were condemned and removed from the track because their strain slightly exceeded 12,000 lbs. per square inch, while pin bridges with 3″ x ¾″ suspenders carrying 15 foot panels were allowed to remain because the orthodox unit stress laid down for such cases was not exceeded.

A properly prepared strain sheet is, as we all know, a very valuable guide in bridge design, if used with intelligence and judgment. Unfortunately the last named proviso has not always been borne in mind; the strain diagram has often become a sort of fetich, and any structure which could be made to conform to it, has been thought fit for use. On many, if not most of our railroads, may still be found bridges, which conform quite well to the usual strain sheet requirements, but are actually far below a proper standard of strength. This may be the case, even where the details and connections are not exceptionally weak, simply because the entire design is bad. It

is a mistake to speak of such structures as being theoretically correct and practically bad. As a matter of fact, the designs are at fault because, they do not take account of important forces and conditions, which need to be considered. They are as bad in theory and as in practice.

**Floors.**—The flooring is the part of the bridge which first receives the weight and impact of the moving load. For this reason it should have an ample margin of safety; both for ordinary conditions and in case of accident to rolling-stock. Derailments are unfortunately of very frequent occurrence, and no floor is well designed, which does not make careful provision for carrying trains, which reach the bridge with one or more trucks off the track or which become derailed on the bridge.

On a prominent railroad, I was informed by the superintendent that there was not a single bridge on his line, the ties of which were not marked by the passage of at least one derailed truck. My own experience tends to corroborate this seemingly exaggerated statement.

The only safe floor is one which is practically continuous and so designed as to allow a derailed wheel to roll over it in safety.

If of timber the ties should be at least 8″ thick and spaced not over 6″ apart in the clear. There should always be guard rails at least 6″ x 8″ fastened to the ties by "dapping" and by bolts which pass through at least every third tie. The ties should extend across the full width of the bridge and be supported on a sufficient number of stringers to insure them against breaking under the concentrated load of a wheel in any possible position.

The *Latimer guard*, a cast iron block which is placed at the ends of the bridge, is a good device for rerailing wheels that are off the track. Even if it does not do this, it will often cause the derailed car to travel parallel with the rail and thus keep it from striking the trusses of through bridges.

The last danger mentioned, that of a passing car striking the trusses, is very great in cases of derailment, and has probably caused the total destruction of more bridge spans than any other cause.

Deck bridges are free from this risk, and for this reason, among others are to be preferred whenever they can be used. They are also more easy to brace laterally, and are less expensive particularly if the timber ties are laid directly on the top *chords*.

The masonry for deck spans is also cheaper than for through bridges, and it will often be found practicable to build a series of short plate girder spans resting on masonry piers for less money than a longer deck through combination or Howe truss. Of course the hydraulic conditions must be such as to allow this arrangement of piers.

Even on deck bridges the floor should be of sufficient width to make the risk of having a derailed train run off into the stream no greater than on the approach embankment on either side. This has rarely

been done, although the widening of bridge floors, is the greatest improvement as to the safety of our bridges that can be made.

A word should be given to the so-called "continuous" iron floor systems. They are quite usual in England and are being introduced on some of our roads, particularly in cities. Such floors, whether built of troughs or simply of I beams covered by top plates make, a very secure platform for trains, whether off or on the rails. The principal objections are their greater cost and the necessity of frequent inspection where the troughs are filled in with ballast.

For trunk lines they have proved satisfactory on the New York Central railroad, and are likely to be used more largely on roads of the better class, though they will hardly displace the wooden floor until timber is much more expensive than at present.

**Conclusion.**—In closing these somewhat desultory remarks, I may be permitted to point out the field in railroad bridge departments which is open to men of proper technical training and experience. In the days when Howe truss and trestle bridges were exclusively used. the bridge superintendents got their training entirely in the work shop and the field.

At the present time, when the most important structures are of iron, there is an opening for men, who have a detailed knowledge of bridge engineering.

Such knowledge can only be obtained by work in the draughting room, the shop and in the erecting gang. It should include experience in the inspection of material in the steel works; the rolling mill and the bridge shop.

All this work cannot be done without much drudgery, exposure to the weather, and soiling of hands, but in no other way can all sides of the subject be mastered.

Some few great engineers are born, not made. But for most of us, success can only be hoped for, as the result of hard, long continued, intelligent effort.

Even the best school training can only help us, by showing us how to approach each subject as it presents itself, in a scientific manner, i. e. divesting it of unimportant side-issues, and allowing the light of our reason to play upon even the smallest questions.

It is this spirit that distinguishes the educated from the uneducated man, the progressive engineer from tbe one who is satisfied with mere precedent.

It alone can lead to success in any field of work, and it will invest the most wearisome mental and physical labor with an intellectual interest.

Let us be thankful that we are members of a profession, the pursuit of which, if carried on in the above spirit, is a constant pleasure and inspiration.

# φ AND ITS DESTRUCTION.

W. D. BALL, '90.

Among the many tribulations which formerly troubled the spirit of the electrical engineer is the angle of lag φ caused by the self induction of alternating current circuits. Although we know now that this trouble can be simply and practically overcome, yet it is in comparatively few cases that this is done and then often by the cut and try method. The so-called practical man says this is all right and that he can produce as good results as the man who has wasted his time studying theory. We do not deprecate experience; it is necessary, but the educated engineer finds that a few figures before hand often saves many dollars afterward.

The writer has recently found that to be the case in a plant that he was called upon to redesign, and it may be of interest to some who have not yet met the problem in practice to take this plant as an illustration and point out the method of campaign for destroying φ.

The load in question consisted of 10,000 incandescent lamps, 125 street arcs, 125 commercial arcs, a street railway using about 100 K. W. and about 200 K. W. in stationary motors.

Now before we can destroy φ we have to find out how large it is going to be, and here is where good judgment is needed as much as much as knowledge. There are three kinds of apparatus in this plant that produce a lag of the current viz., rotary field motors, transformers and arc lamps. The latter are constant and easily calculated, but the self-induction of the motors and transformers varies inversely with the load. The only thing that can be done in a case like this is to find the worst possible condition and make arrangements to take care of this. If, however, we have neutralized the largest angle of lag, we will produce a leading current, which is just as harmful, when this angle of lag in the circuit decreases. It is easy enough to vary this neutralizing effect but the trouble is to know just how much neutralization is needed. There is no commercially practical instrument, to the writer's knowledge, which can be used for showing the angle of lag in a circuit though he has just designed a very simple instrument for this purpose. It is as yet only on paper, but if we can get such an instrument, it will be a simple matter for the station attendant to adjust the neutralizing effect as the lag varies, provided the variations are not too sudden and violent.

It might be well to give the assumptions and calculations that were made in the above case for calculating the angle of lag.

The alternating current arc lamps to be used, took 6 amperes and burned at 70 volts D. P. across the arc. Inasmuch as it was necessary to have an economy coil in the lamp for the sake of steadiness, it was determined to use the same voltage for them as for the incandes-

cents; namely 115 volts. It was found that to put them on the same secondaries would not appreciably affect the lag in the secondaries with the given number of lamps in circuit.

The apparent watts per lamp was $115 \times 6 = 690$. The actual watts according to the manufacturers was 450. The power factor would be then cos. $\Phi = \frac{450}{690} = .652$.

Now in dealing with circuits containing resistance and reactance we have to do with vector quantities, and if these resistances and reactances are in parallel, it is necessary to add vectorally the reciprocals of the quantities in order to get their combined impedance. The simplest way to do this is to find the horizontal and vertical components of these quantities both in direction and magnitude add algebraically all the horizontal components together and all the vertical components together and then find the resultant of these sums. This gives the reciprocal of the impedance in direction and magnitude.

Taking the reciprocal of this gives us the impedance and, the direction being known, the resistance and reactance factors are at once determined and from them the angle of lag.

The worst condition that will probably obtain on the lighting circuits if the arcs are fed from the same transformers as the incandescents is a load of 4000 incandescents and 125 arcs.

The reciprocal of the resistance of one incandescent is .00425 which should be plotted horizontally. The impedance of one arc lamp is 19.17, the resistance 12.5, and the reactance 14.56. Describing this triangle we have the direction of the impedance. Taking its reciprocal and resolving it into its components we find the horizontal or $\frac{1}{R}$ component is .034 and the vertical or $\frac{1}{L}$ component is .07.

Adding then all the horizontal components we have $(.00425 \times 4000) + (.034 \times 125) = 20.25$. The sum of the vertical components is likewise $.04 \times 125 = 15$. The reciprocal of the combined impedance on the secondaries then is $\sqrt{20.25^2 + 15^2} = 20.8$ approximately. Hence the impedance is .048, the resistance is .0466 and the reactance .0115. The power factor in the secondaries is $\frac{.0466}{.048} = 97\%$.

Now the worst condition to be taken care of in this case will probably take place during the day when the load consists mostly of motors. It is impossible to determine before the plant is in operation what the load and consequent self-induction will be so we must judge from the circumstances of the case and assume what the average load will be. Having this determined, the power factor for both the motors and transformers is obtained from the curves showing the relation between the load and self-induction.

The average load was calculated to be 225 K. W. for the motors, 50 K. W. for street railway and 70 K. W. for incandescent lights, the arc light being shut down during the day. The power factors were

found to be .85, .80 and .70 respectively, of which the combined power factor is approximately .81, giving a lag of 36°.

It is necessary then to install such apparatus as will neutralize this lag. This, a synchronous motor or rotary transformer will do. In the station in question both will be in use, rotary transformers to operate the street railway and a synchronous motor to run a street arc light machine. Either or both of these machines could be used and they would be required to have their fields overexcited to such an extent as to give a current with 36° lead. Moreover the capacity of the machine used must be at least equal to the excess current required by the power factor found. This current is $\frac{W}{V} \times \frac{1}{\cos \varphi}$ where W = watts and V = E. M. F. When using 240 K. W. at 2,300 volts, the motor must have a current capacity of at least $\frac{240,000}{2,300} \times \frac{1}{.81} = 129$ amperes. This requires a 75 K. W. motor.

If a load curve can be obtained, a similar calculation should be made for other loads so as to be sure that the maximum condition of lag is found. In the particular case in question this was done and the above found to be the maximum.

It was a particularly fortunate circumstance that the old plant had a 90 K. W. arc machine and a 150 K. W. generator. The latter was to be used as a synchronous motor to drive the former in which case there would be plenty of capacity left to take care of the lag.

It often pays to install a synchronous motor and run it idle simply to compensate for lag. It can be readily seen that a great part of the money spent for the motor can be saved in generators and also the cost of the I²R losses saved. It can be calculated in all cases whether or not it would pay to install a motor for this purpose by charging the interest on the investment plus the depreciation against the yearly cost of coal to supply the I²R loss.

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## LAW HINTS FOR ENGINEERS

GEO. W. TILLY, Jr.

It is now a recognized fact that the engineer should at least know the fundamental principles of law as applied to matters with which he must constantly deal. Recognizing the importance of such general knowledge and its advantage to the engineer, some of the technical schools have provided for their students lectures on the law of [illegible] and a few points can be touched upon in the limits of this article. It is hoped that the directions in which investigation may profitably be extended, may at least be in part pointed out. It will be neces-

essary to confine our attention to a few points, leaving many important questions untouched.

Of those not touched upon it may be well to suggest that the law of Riparian rights, accretions and relictions, the law of eminent domain as applied to engineering enterprises, the right of owners of buildings already built or unobstructed light, and to support of such buildings by adjoining land, preventing removal of earth so as to endanger the foundation of such building, the law of surveys, etc., should also be investigated by the engineer who wishes to be well equipped for his work. It is not supposed that the engineer will become a lawyer, but that he should have sufficient knowledge of law to guide him in his every day duties in the ordinary questions which arise in his practice.

### THE ENGINEER AS AGENT.

An engineer in his relations to his employer is an agent, and his duties, powers and liabilities are in a large measure determined by the law of agency. He has, ordinarily, only special powers, namely, to engineer and superintend the work in hand and to direct it in accordance with the terms of the contract. He has no power to make a contract on the behalf of his employer nor to modify a contract already made, unless specially empowered to do such acts. It is his duty as agent to adhere strictly to the terms of the contract and his instructions.

As agent the engineer must act in good faith with his employer. An instance of bad faith is a case where the engineer is secretly interested in the contract and receives part of the profits derived by the contractor for performing the work, or is also employed by the contractor without the knowledge of the owner who employs him.

There is one element in the relations of the engineer and his employer which does not always exist between an agent and principal. The engineer by undertaking to act in his professional capacity, impliedly contracts that he is possessed of at least the average degree of learning and skill in his profession, and that he will exercise his skill and learning with reasonable fidelity and care; and he is liable to his employer for loss occasioned by his lack of such professional knowledge and skill, or by his negligence in the performance of his duties.

Judge Cooley says: "He does not undertake for extraordinary care or extraordinary diligence any more than he does for uncommon skill." Reasonable care and fidelity he must exercise. And by this is meant such care and fidelity as an ordinarily prudent and careful engineer would exercise.

Another important rule of the law of agency should here be noticed. The owner or principal employing the engineer, is charged with knowledge of matters relating to the work which are known to the engineer. This is true whether the engineer has reported such matters to his employer or not. One duty which the engineer owes to

his employer is to promptly give him notice of such things coming to his knowledge as may effect his obligations to others. It has been held that the employer was bound and could raise no question of the due completion of a contract, if his engineer, who had watched the progress of the work, and inspected it while being done, and so knowing the character of the work performed, had given his certificate of the completion of the work and the amount due the contractor.

By the law of agency it is a general rule that a person to whom certain powers have been given cannot delegate such powers to another. This rule does not require the engineer to do all of the mechanical and ministerial part of his work himself, but it is well recognized that such duties may be performed by others under his direction. It is not practicable for him to do all himself. There are four exceptions to the rule:

1. When there is a lawful custom or usage to authorize it.
2. When the act is purely ministerial. By this is meant the doing of anything by the command or at the direction of another.
3. When the object of the agency cannot be otherwise obtained.
4. When the principal is aware that his agent will delegate to others part of his powers and duties.

All four of these exceptions may apply in case of the engineer's agency, and he may have others to assist him. Matters of judgment and discretion should be decided by the engineer.

## THE ENGINEER AS QUASI-ARBITRATOR.

It is often provided in construction contracts that to prevent disputes and litigation, the decision of the engineer as to all questions in relation to the work and the measurements, quality, quantity, extra work, etc., shall be final, and from such decision there shall be no appeal.

Under contracts with such provisions the engineer is clothed with power to decide or judge between the contractor and owner. So far he is an arbitrator and his powers, duties and liabilities under such a clause are in a large measure distinct from his powers, duties and liabilities as the agent of his employer. Here he acts in a judicial capacity and in his character as quasi-arbitrator, he is not liable to suit for loss occasioned by his wrong decision unless it is shown that he has been dishonest and fraudulent. All that is required of an arbitrator is that he shall act honestly and be faithful in the performance of his duties to the best of his judgment; and he is not required to bring any particular skill to the performance of the duty.

A contractor cannot recover from him except when loss is occasioned by his fraud and dishonesty. He is still liable to the owner or his agent for loss occasioned by his lack of skill or due care. His relation to his employer is dual but to the contractor it is only that of arbitrator or quasi-arbitrator.

Objection has been waged against the provision commonly put into construction contracts, making the decision of the engineer final, because the engineer is usually employed by the owner to superintend the work and look after the interests of his employer. He is, therefore, they say, not an impartial arbitrator, and one who is to thus decide questions arising between the owner and contractor as in any other case of arbitration, should be an impartial judge. On the other hand since the contractor knows when he signs the contract that the engineer is employed by the owner, it is not unjust that he should be subject to the provisions of the contract. Courts have frequently held that only such an interest as is unknown to a party to such an agreement will bar a person from acting as arbitrator.

It has been the custom in a very few localities for the parties to provide in the contract that a disinterested engineer should be employed. In such case his compensation is paid in equal shares by the parties to the contract. Should this custom become general it would certainly add much to the honorable professional character of the engineer's practice and would leave him free to exercise his best judgment in matters of difference between the parties, without any influence of his personal interest to even tend to turn his decision in favor of either party.

## THE STATUTE OF FRAUDS.

All or nearly all the states have enacted what is called "The Statute of Frauds," either as it was enacted in Great Britain or in a modified form. Some of the provisions of this statute, which is very much alike in the various states, may be profitably considered here. By this statute every contract which is not to be performed within one year from its date must be in writing and signed by the parties. A case which may become of interest to the engineer, is an employment for one year to begin at some date subsequent to the date of the contract. In such case if the contract be oral, it cannot be enforced and the employer may refuse to permit the engineer to commence work under it, and the engineer will have no right of action.

A contract for the sale or transfer of land or any interest in land, must be in writing. It has been held that permission to one to erect a building or a bridge on the lands of another, or leave to occupy land by a railroad, a dam or a canal, or to overflow land by a dam, or to dig and remove coal, ore, gravel, etc., since it is a contract for an interest in land must be in writing.

A contract to answer for the debt, default or misdoing of another, must be in writing. A bond to secure the performance of a construction contract, is such a contract and if not in writing the sureties cannot be held liable on the bond.

## CONSTRUCTION CONTRACTS.

Every contract in order to be binding must be entered into by two parties competent under the law to make a contract. It is a fundamental principle of the law of contracts, that the minds of the parties must meet and agree in order to make a contract. If a person is not of sufficient mental capacity, by reason of being an imbecile, lunatic, idiot or confirmed drunkard, a contract made by him is not binding because it may be proved that he is of insufficient mental power to be capable of reasoning and forming a judgment as to what is for his benefit. The law, therefore, guards against unfair advantage being taken of such persons, as also in the case of infants, by which term is meant persons under twenty-one, or in some states males under twenty-one and females under eighteen years of age. The party who is competent, is bound although the infant may avoid it. At common law a married woman cannot make a valid contract, but most of the states, in these modern times when women are coming to the front, have enacted statutes empowering married women to contract. If in the state where a contract is entered into and to be executed there is no express provision of this kind, no contract should be made with a married woman as one of the parties.

An engineer or any agent, may, if duly authorized, make a contract which is binding upon his principal; but in such cases it is best that the authority be expressly recited in the contract and it should appear that the agent is making the contract for and in behalf of the principal whose name should be set out in the written instrument.

In entering into contracts with public officials or officers and agents of public corporations, every one is bound at his peril to ascertain the extent of their authority, because a public corporation is not bound unless its agents act strictly within the authority delegated to them by the act of incorporation or by law.

An engineer whether a contractor himself or acting as engineer for the contractor or for the public corporation, should thoroughly inform himself of the extent of the authority of its officers and agents. It is too often the case that contracts are entered into, or subsequent changes in contracts with public corporations are made without a due regard to the authority possessed by their officers. Officers and agents of public corporations frequently on their own motion order changes made which can legally be made only by an act of the council or some other authorized body.

So in the case of other corporations. The officers or agents must in some manner be authorized by the board of directors, trustees or other governing body, to enter into a contract for a proposed construction work or their contracts therefor will have no binding effect. Any one contracting with such unauthorized officers or agents, does so at his peril, for the corporation would not be liable under such a contract. Such corporations are also limited by their charters or by

general law and any contract entered into by a corporation for the making of any improvement which such a corporation is not authorized to make by reason of the limitation of its powers and objects, is void because it is *ultra vires*, or beyond the powers of such corporation.

The system of letting contracts for important works after advertising for and receiving bids, which is so common in this country, makes this subject a matter of importance to every engineer. This is one way of arriving at an agreement and making a contract. A bid or proposal is merely an offer to do some particular work or furnish some specified materials for a stipulated compensation. If, before it is withdrawn, it is accepted by the person or corporation intending to have the work done, a binding contract exists between the parties. A certified check is usually required to be deposited with each bid; and this is forfeited if the bidder withdraws his bid.

Public corporations are usually required to advertise for proposals for such public improvements as are to be made, and to award the contract to the lowest responsible bidder. Unless the advertisement is properly made, for the required length of time and in all respects as required by law or the ordinance or charter of the public corporation, no valid contract can be made. Such a contract can be made only in the manner provided by the law.

Private owners can, of course, make such rules and have such bids submitted in such form, as they may see fit.

The terms upon which bids are to be made should, in every case, be made clear and definite so as to show the exact terms of the contract, and the subject matter of the bids should be definitely described. To this end the plans and specifications submitted to intending bidders should be carefully drawn so as to show every item which the bidder needs to know to prepare his proposal, and so as to have all bids upon the same basis. When a bid is accepted a definite contract is made on the terms then agreed upon; and if either party refuses to execute the contract he is liable in damages to the other party.

It has been held that any of the negotiations, or any conduct or [illegible] have the work done, which shows that he assents to [illegible] him.

When a contract is reduced to writing and signed by the parties, [illegible] contract and no evidence of what was said during the negotiations, the contract, will be [illegible] its terms. The written contract is [illegible] stipulations of the parties. [illegible] evidence to explain technical [illegible] inconsistencies, either between the contract

[illegible] complete expression [illegible] two separate con-

[illegible] entered into at the same time. Both of such contracts may be written, both oral, or one written and the other oral. It must be borne in mind, however, that each separate contract must have its separate and independent consideration. Subsequently to making a contract a written or oral agreement may be made either modifying, or superseding the original contract. If there is a new consideration. The consideration for the second contract may be the mutual release of some rights under the previous contract. It is not necessary that the consideration be money, but may be, for instance, a piece of work or a certain amount of the owner to require [illegible] to do work done in the manner provided in the original contract.

If a contract is executed, that is, has all of its terms performed, it may be rescinded by mutual consent, but if it has been executed by one of the parties the consideration for such rescission does not exist and it can only be rescinded by a new consideration.

[illegible] contract is to be construed by the statute of frauds to be in writing the mutual intention must appear in writing. It must be, [illegible] a contract not to be performed from the date upon which it is made or a contract for the sale of [illegible] must be in writing, [illegible] must be in writing.

[illegible] take for granted that the contract is complete in all its [illegible] the specifications and drawings made a part of it, and that they form the whole of the agreement between the parties. It is usual to provide for certain [illegible] the progress of the work. The penalties and [illegible] made a part of the contract, and should be made a part of the contract by some reference, [illegible] left to the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] necessary. A method of [illegible] the parties to the contract [illegible] to make them a part of the contract.

## EXTRAS AND ALTERATIONS.

A large part of the litigation [illegible] contractors arises out of contracts [illegible] extras and alterations. Some contracts provide [illegible] getting [illegible] prices for extras, [illegible] many [illegible] extras as [illegible] extras therefore [illegible] answer. It may be stated [illegible] extra that any work [illegible] contract [illegible] [illegible] contrary is true. But if the work [illegible] with the

request of the owner and was not required by the contract the contractor may recover for it as an extra.

The circumstances which may determine the question are so various that it is impossible to discuss them at length in the short compass of this article. The authority of the engineer is not usually such that he may order extra work done and bind his principal, and the contractor who does such work at the request of the engineer or other person employed to superintend the work, cannot recover.

This is especially true as to work done for a city or other public corporation, merely at the request of the engineer or other agent employed by such corporation. Express authority must have been given or no liability of the owner exists for such work, and the owner may refuse to pay for it. The conduct or language of the owner, after gaining knowledge of such work being done, may, however, be such as to work a ratification of the acts of his agent and he will then be bound.

Many have wisely inserted into construction contracts a provision to govern the allowance and payment for extras. It is common to provide that no extras will be paid for unless the order for the work shall be in writing and the price for the work agreed upon and endorsed upon the original contract. Under such a contract no compensation can be recovered for extra work unless such formalities have been complied with. Even such a contract may, however, be modified by subsequent oral agreements, or the assent of the owner to a lax observance of the contract and permitting extra work to be done and paying for it may work a waiver of such provisions and a modification of the contract so that the owner may become liable for the payment of large amounts for extra work done without such order and formalities. The only safe way is to constantly insist upon a strict observance of the contract. This provision will serve as an illustration. Others might be cited.

One other clause is an express waiver of all claims for extras; but it has been doubted by many whether it is wise to insert such a provision. It tends to cause contractors to demand higher prices for work as a kind of insurance against loss by reason of extra work made necessary by unforseen circumstances.

In making any changes in plans or in the contract, care should be taken to acquaint the sureties on the contractor's bond with the facts and secure their consent, because they are released if changes be made without their consent. If a person has signed a bond for the faithful performance of a contract, his suretyship extends only to the original contract. If the contract contains a provision for changes in the plans and specifications and the contractor has agreed in the contract to make any alterations which the owner may require, the surety is not released because modifications are made, such changes being contemplated and provided for in the contract, the performance of which he has guaranteed.

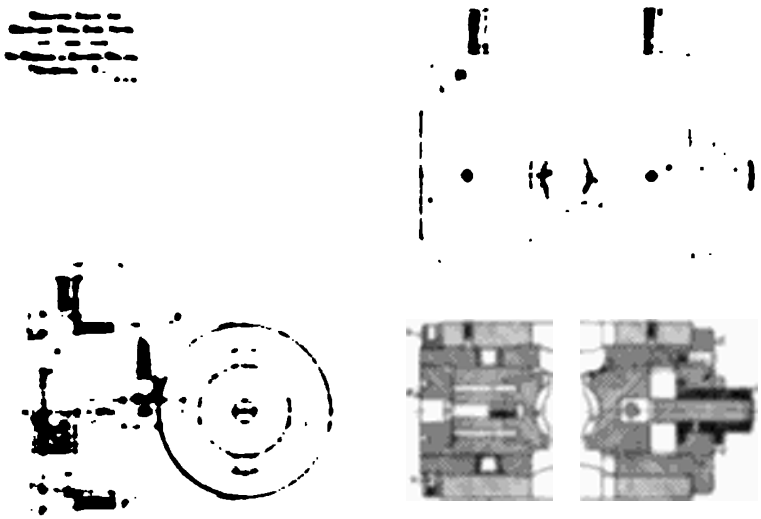
[illegible] provides for withholding part of the payment [illegible] payment is due before completion will release the [illegible] The surety is released if it becomes impossible for [illegible] without fault of the contractor. As for instance if the [illegible] destroyed by [illegible] and cannot be [illegible] the retained percentage is released.

[illegible]

## REVOLVING CHUCK

[illegible]

[illegible] illustrates a [illegible] designed by [illegible] the Navy Yard, Mare Island, California, Department of the Bureau [illegible] Manufacturing Co. This tool is designed for boring [illegible] [illegible] the chamber shown in the [illegible] The [illegible] [illegible] [illegible] [illegible] are drilled through



[illegible] faced on two sides of the body and the [illegible] [illegible] the fourth side is left [illegible] The [illegible] consists of a [illegible] which can be rotated, so as to prevent any [illegible]

openings which may be desired, and the means provided for holding and operating the chuck jaws. The face plate is threaded to fit the nose of the spindle of our No. 4 Screw Machine on which the chuck is to be used. It is held to the chuck body by three radial screws at angles of 120°, and by four horizontal clamp screws. The radial screws are tapped into the face plate, and have their heads overlapping the edge of the chuck body. These are for the purpose of centering the chuck, as it is usually found for accurate work, that such a chuck has to be lined up when it is put on any particular machine, even if it had been previously, carefully lined up on some other machine. The horizontal screws are used to clamp the chuck to plate after adjustment are made with the radial screws. The cylinder "A" which holds the chuck jaws, is accurately indexed through 90°, and drilled and hardened steel bushings inserted for the locking pin shown. This locking pin is operated by means of a rack and pinion movement, a rack having been cut on the upper side of the locking pin. The pinion is rotated by means of lever shown, and is held in place by a tit screw, having the tit let into a slot in the pinion.

Referring to the vertical section, one pair of chuck jaws "D" "D" for holding a ball nut are shown in position, the one at the left being fixed as regards cross-wise movement after having been once set in the proper position by the nut "E" shown just behind the body to which the jaw is fastened. The one at the right is moved cross-wise for clamping and releasing, by rotating the bronze nut "F" with a suitable wrench. The large nut "G" at the left enables perfect adjustment for taking up all lost motion of the cylinder cross-wise, and is held in position by set screw, and brass clamp plug "H." At the right hand end, the bronze nut shown, is held in a cap "J," which is in turn held in the cylinder "A" by an arrangement similar to method of holding a gun-breech by an interrupted thread; *i. e.*, the cylindrical wing on the cap is cut away in four places, which will pass through four openings in the cylinder "A," and when rotated 45°, the two coincide. They are then held in that position by the screw plug shown. The methods of oiling are quite obvious. This tool has proven very efficient and satisfactory in accomplishing the purpose for which it was designed.

NEW YORK, May, 1898.

# LEVELING IN CONNECTION WITH THE DETROIT WATER WORKS.

[illegible] W. HUBBELL, M.[illegible]

The first item is a constant due to elevation, and its measure between any two points is the difference of elevation between those points. In order to determine this constant the elevation of each gauge must be known, and it is the purpose of this paper to describe more particularly the work of connecting gauge stations by means of intersecting lines of closed levels. For while there is a goodly amount of literature on levels and leveling, it for the most part describes long lines of what is termed precise leveling and does not apply to work of the nature hereinafter described.

The levels required aggregate about eighty miles and consist of a number of intersecting loops, each loop closing either on the place of beginning or on some point of known elevation. A net work of intersecting lines is thus obtained which offers a favorable opportunity to observe the accuracy attainable in short lines of closed levels, and although sixty miles is not enough upon which to base conclusions, at least a clue may be found as to the factor of precision to be reasonably expected under similar conditions.

The City of Detroit is situated on gently sloping ground which rises gradually as it recedes from the Detroit River. The grade is about twenty feet per mile until an elevation of perhaps sixty feet above the river is reached, after which the ground is nearly level. Nearly all the lines of levels follow paved streets upon which there is considerable traffic. It was frequently necessary to set the level on the pavement itself, thus subjecting it to more or less jar from passing teams. Some difficulty was experienced on account of the dust especially on lines run in dry, windy, summer weather. Part of the lines were run during cold weather when keeping notes was unpleasant and when great care had to be exercised to prevent the tripod shoes from settling in the ice or frozen ground. The same level and rod were used for the entire work; the levelman and rodman were, however, changed from time to time thereby eliminating to a large extent the equation of personal error. Backsights and foresights were kept as nearly equal as possible by pacing and were usually about three hundred feet each. During the heat of the day sights were sometimes reduced to two hundred feet and if the air boiled too much, work was stopped for two hours or more during the worst part of the day. Each levelman received instructions to do his very best work. A party consisted of a levelman at a cost of say $5.00 per hay, and the average speed was 1.8 miles per day: cost per mile $2.80.

**Instruments.**—The rod used is of the kind known as an architect's rod made of two pieces of hard maple ¾-inch square, reading 5.300 feet when closed and 10.000 feet when extended. It is graduated like a N. Y. Rod and furnished with vernier reading to one-thousandths of a foot. The target is 3½ inches in diameter and quartered red and white. In September, 1897, the target was improved by pasting a piece of paper over its face and painting it all black with the exception of a horizontal shouldered slot 0.010 of a foot wide at the outside

edge of the target and 0.08 of a foot wide at the center. Before changing it was difficult to detect an error in setting of 0.02 of a foot on a sight 300 feet long, but with the slot it would be detected every time, even in poor weather, and did not seem to tax the eyes so severely.

Buff & Berger's Wye level No. 2888, 18-inch, erecting telescope was used for this work. The bubble scale is divided into inches and tenths, the angular value of one division was determined April 27, 1898, under the following condition

Temperature about 60° Fahr. Base 300 feet long measured with steel tape. Level set up in shade of Hurlbut gateway. Rod held in bright sunlight. Air a little shaky and a light breeze blowing. The mean of six observations gives results as tabulated below

| | | | | |
|---|---|---|---|---|
| 0.75 | 0.125 | 0.0151 | 0.0025 | [illegible] |
| 0.15 | 0.100 | 0.0164 | 0.0005 | [illegible] |
| 0.25 | 0.075 | 0.0151 | 0.0010 | [illegible] |
| 0.35 | 0.075 | 0.0150 | 0.0011 | [illegible] |
| 0.40 | 0.100 | 0.0147 | 0.0012 | [illegible] |
| 0.50 | 0.115 | 0.0164 | 0.0005 | [illegible] |
| 2.80 | 0.450 | 0.0161 | | [illegible] |

0.2
2.8
0.0175
6

0.0170
0.0170

Probable error 0.745 [illegible] Johnson [illegible]

0.745 [illegible]
0.0148

Value of one division on bubble scale 0.0164 0.0005 ft. on rod 300 ft. from rest.

Value of one division on bubble scale [illegible] seconds
0.0164 0.0005
[illegible]
11.3" ± 0.3" seconds of arc.

Attention is called to the fact that one division on the bubble scale corresponds to 0.016 of a foot on the rod when placed 300 feet distant from which it follows that if the center of the bubble is $\frac{1}{100}$ of an inch either way from the center of the scale when a reading is taken, an error will be introduced of about one and one-half thousandths of a foot. As $\frac{1}{100}$ of an inch is pretty close work, especially where it has to be determined by estimating by eye the tenth of a division on the scale for each end of the bubble, it seems likely that an error of 0.002 of a foot from this source would not be unusual.

One-tenth of an inch on the bubble scale should have an angular value of from eight to ten seconds of arc in order to correspond to the factor of precision with which it is possible to set the target at 300 feet distance.

The following table gives the distance in miles and the closing error in feet for fifteen closed loops. The three lines showing the greatest discrepancies were run under conditions more unfavorable than usual, as noted on margin.

TABLE NO. 1.

| No. | Dist. Miles. | Closing Error Ft. | | | |
|---|---|---|---|---|---|
| 1 | 2.4 | 0.028 | Single | loop. | |
| 2 | 2.4 | 0.045 | " | " | |
| 3 | 2.4 | 0.012 | " | " | |
| 4 | 2.4 | 0.042 | " | " | |
| 5 | 2.4 | 0.047 | " | " | |
| 6 | 2.4 | 0.002 | " | " | |
| 7 | 2.5 | 0.010 | " | " | |
| 8 | 4.4 | 0.007 | " | " | |
| 9 | 6.1 | 0.062 | Combined | " | Very hot and dusty. |
| 10 | 7.2 | 0.031 | Single | " | |
| 11 | 7.8 | 0.001 | " | " | |
| 12 | 8.5 | 0.078 | " | " | Winter. |
| 13 | 15.0 | 0.032 | Combined | " | |
| 14 | 18.5 | 0.031 | " | " | |
| 15 | 23.5 | 0.140 | " | " | Part Winter. |

**Remarks.**—Lines No. one to six inclusive were run between the U. S. Bench mark at the foot of Mt. Elliott Ave., and a bench mark established on the Hurlbut gate at the entrance to the pumping works grounds and make the elevation of the latter 104.478 ± 0.010 feet city datum. The maximum closing error as will be noticed in the table is only 0.047 for the line showing the most closure. This result is checked in an unexpected manner by five lines of levels run in 1895 in connec-

tion with the laying of a line of 42 inch pipe between a bench mark at the corner of Chene and Champlain streets and a bench mark on the stone coping of the fence near the Hurlbut gate, a distance of 2.6 miles these levels were carelessly run and are not considered accurate no special pains having been taken to do good work, in fact part of them were run with a rod which could be read to hundredths only. Both ends of these levels were afterwards tied with accurate levels, the probable error being only 0.011 of a foot. Making the proper transfer the elevation of the Hurlbut gate B. M. is as follows

| No | Elevation | Error |
|---|---|---|
| 1 | 104.950 | +0.444 |
| 2 | 104.511 | +0.005 |
| 3 | 104.042 | +0.166 |
| 4 | 103.911 | 0.266 |
| 5 | 104.088 | +0.222 |
| Mean | 104.176 | |

The mean value 104.176 ± 0.151, obtained by this series varies 0.262 of a foot from the value obtained by the more accurate determination given in table No. 1. The close agreement of results is a coincidence that would not be expected from an examination of the closing errors from which it is seen that the mean value depends on one having a closing error of nearly a foot, the only negative result in the series and one which on more inspection would probably be rejected altogether. Line No. 11, which shows the least closing error in the table when checked at about the middle of the work, has a probable error of 0.017 while the closing error is only 0.031 of a foot from which it is seen that it is not always safe to assume that the error of a bench mark established lies within the closing error of the circuit upon which it is located.

All elevations and Bench Marks established are referred to the B. M. on the light-house building at the foot of Mt. Elliott Ave., established by the United States Engineer Corps Survey of the Great Lake Region between the years of 1871 and 1877, the elevation being 104.48 city datum and 581.78 above mean tide in New York harbor. The plane to which the elevations above mean tide are referred is that adopted by the Lake Survey and corresponds to an elevation of 14.7 above mean tide at New York for the Bench Mark on the granite monument at Greenbush, New York established by the Coast Survey in 1877 and 1894. Mr. C. H. Van Orden has made a second determination of the permanent Bench which corrects the elevation a little over a foot. If the later elevation proves correct, and there is some evidence that

it may,* the elevation given (584.78) will be subject to a negative correction of one foot more or less.

The table below is one which appears in the paper by Mr. Wilson referred to in the preceding foot note and shows the closing errors of thirty-four lines of levels ranging from seventeen to one hundred and nienty-five miles in length. These levels were run at an average cost of $4.78 per mile, and ranged in cost from $2.79 to $8.17 per mile according to locality. The instruments used were Gurley 20″ Wye Levels with level bubbles graduated to ten seconds of arc, and New York rods fitted with taper shoes one inch in diameter at bottom.

TABLE NO. 2.

| Length of Circuit Miles | Closure Error Feet. | Length of Circuit Miles. | Closure Error Feet. |
|---|---|---|---|
| 80 | 0.020 | 60 5 | 0.082 |
| 69 | 0.016 | 21 | 0 370 |
| 35 | 0.042 | 20 | 0.080 |
| 29 | 0.027 | 80 | 0.295 |
| 45 | 0.395 | 36 | 0.120 |
| 17.5 | 0.051 | 19 | 0.145 |
| 26 | 0.007 | 95 | 0.208 |
| 112 | 0.284 | 41 | 0 018 |
| 94 | 0.216 | 51 | 0.103 |
| 30 | 0 058 | 195 | 0.420 |
| 52 | 0 014 | 70 | 0 240 |
| 33 | 0.033 | 70 | 0 150 |
| 30 | 0.043 | 42 | 0.100 |
| 32.5 | 0.270 | 170 | 0.100 |
| 41.5 | 0.343 | 72 | 0.183 |
| 116 | 0.608 | 57 | 0.233 |
| 75.5 | 0.260 | 33 | 0. 20 |

The limit of error in feet allowed by the U. S. Geological Survey $= .05 \sqrt{\text{dist. in miles.}}$

The limit of error in feet allowed by the U. S. Lake Survey $= .04 \sqrt{\text{dist. in miles.}}$

The limit of error in feet allowed by the U. S. Coast and Geodetic Survey $= .03 \sqrt{\text{dist. in miles.}}$

The limit of error in feet allowed by the U. S. Missouri River Commission $= .02 \sqrt{\text{dist. in miles.}}$

These four parabolic curves have been platted in connection with the closure errors of Table No. 1, and it is found that all errors lie

* See report of U. S. Deep Water Ways Commission 1896. pp. 79 to 82, also paper presented before the Am Soc. C. E., Feb. 16, 1898, by Mr. Herbert M. Wilson, on Spirit Leveling of the U, S. Geological Survey.

within the limits of .03 $\sqrt{\text{dist. in miles}}$ set by the Coast and Geodetic Survey, while only five fall without the most severe requirement of the Missouri River Commission or .02 $\sqrt{\text{dist. in miles}}$.

The accuracy with which elevations are determined is greater than that attained in reading gauges. An inexperienced observer will seldom read the vibrating pointer of a gauge closer than a quarter of a pound (= 0.58 feet) and a half pound error is not infrequent. An average of twenty-four hours would therefore be liable to an error of one-tenth of a foot or more, while the probable error of elevations in no case exceeds ±0.04 and is seldom greater than ±0.02 of a foot. From time to time, however, special tests are made with more accurate instruments and experienced observers, in which the degree of accuracy attained is not far from that with which the elevations are determined.

**Results.**—In conclusion a few words as to general results obtained may not be out of place. The frictional loss in the system as a whole has been decreased about 45% or 50%. This means simply, that the pressure required to push a given amount of water through the pipes of the distribution system is now only about one-half what it was in 1893. This saving in pressure is particularly significant in view of the fact that the pumping engines, while capable of delivering considerably more water than has yet been required of them,—had in 1893 very nearly reached the limit of allowable pressure for which they were constructed. The cost of readjusting the system has been about $325,000, which is partially offset by a saving of 12½% in fuel bills. In 1896 the fuel bill was $31,186.17, burning oil. In 1897 it was $17,355.58, burning soft coal. The saving in 1896 at 12½% would be $3897.77 and in 1897, $2,169.44. A low estimate of the average saving may be placed at $2,400 per annum. This capitalized at 3% represents an investment of $80,000.00, and leaves the net cost of improvements say $240,000 in five years, an average of $49,000 per year. This showing compares very favorably with expenditures in previous years, which however did not accomplish the desired results.

The most important benefit derived in the equalization of pressures so that up-town residence districts which formerly had from eight to ten pounds pressure now have from fourteen to sixteen pounds without increasing the initial pressure at the pumps. In these districts, buildings, which in 1893 had water on the first floor only, are now enabled to place both tubs and fixtures on the second floor, and at the same time feel secure in knowing that there is a sufficient supply of water available for fire protection.

# RESULTS OF EFFICIENCY TESTS ON THE ENGLEWOOD AND CHICAGO ELECTRIC STORAGE BATTERY ROAD.

GEORGE A. DAMON, B. S. '95.

One of the marked features of electrical progress in this country during the past two years has been the rapid advancement of the storage battery. Nearly three million dollars worth of accumulators are being used today in isolated plants, in central power plants, or in substations, and the advantage gained by their use are now well recognized. As the TECHNIC goes to press this year the largest battery ever made, consisting of 332 cells, each of 11,000 ampere hour capacity, is being thrown across the mains of the Chicago Edison Co., and the successful inauguration of this immense battery coincides very nearly with the first anniversary of Chicago's storage battery road, which for about a year has been attracting widespread attention. This road, which is the largest of its kind in the world and the only one in this country is now operating twenty motor cars over twenty-four miles of track in the suburbs of Chicago. It is not the intention of this article to describe the equipment of this installation as detailed descriptions have appeared in a number of the technical papers.*

In the fall of 1897 it was decided by Mr. G. Herbert Condict, then general manager, to make a test of the road and its model power plant to determine the most economical methods of operation. The tests were put in charge of the writer with no further instructions than to make them complete. Through the kindness of Prof. T. P. Gaylord, whom many TECHNIC readers will recall as a member of the Class of '93, the equipment of the Armour Institute of Technology was made available, while the students of that institution assisted during the entire test which lasted over a month.

The report of the tests has been abstracted quite generally by the technical press† and has also been published in part by The Electric Storage Battery Co., of Philadelphia, in a pamphlet issued March 1, 1898, and which may be had for the asking. It is not the intention to republish these results at this time, but rather to call attention to some of the interesting engineering conclusions which may be reached by a study of the data collected during the tests. For this purpose the graphical log of the observations as shown in Figures 1, 2, 3, 4 and 5 will be of value. It will also be necessary to state that the equipment of the power plant consists of two 250 horse power triple

* Western Electrician, August 7, 1897.
Engineering News, January 6, 1898.
Street Railway Review, February 15, 1898.

† Western Electrician, February 6, 1898.
Electrical Engineer, February 3, 1898
Engineering News, February 3, 1898.
Street Railway Review, February 15

expansion engines of the Willans type taking steam at 180 lbs. pressure from three Heine water tube boilers and exhausting into Worthington jet condensers. The injection water is obtained from a cooling tower (Figure A). The duplex pumps exhaust into a closed heater and the feed water water is taken from the condenser discharge pipe and on its way to the boiler passes in series through the heater and a

Fig. A. Cooling Tower and Economizer.

Greene economizer in the smoke flue. The engines run at 380 r. p. m., and are connected to the six pole shunt wound Walker 190 K. W. generators by means of the "Arnold System" (Figure B) in much the same way as in the University plant with the exception that in this case four generators are installed between the engines instead of two, in such a way that either engine can operate any one or all four of the dynamos.

Lack of space will not permit giving a complete description of the scheme of the tests nor of the precautions adopted to secure accurate observations on the coal and water consumed, as well as on the output of the engines and generators.

All scales, steam gauges, thermometers, indicator springs, electrical and other instruments used were either the standard apparatus of the Armour Institute, or were carefully calibrated. Eight indicators were required to obtain the horse power of each engine.

The first test was with the plant running with two boilers, two

engines and three generators. The second test was with practically the same load carried by one boiler, one engine and two generators, while the last test was made under practically the same conditions as the second test, with the exception that the three voltage method of charging the batteries was abandoned. In this test but one generator was used, and the batteries were charged in successive sets, all at a common potential, the voltage being raised, as the batteries became charged, in such a way that the load upon the generator was kept nearly constant.

The coal used was from Fairmount, W. Va., and cost, delivered at the power house, $1.90 per ton. An average of five determinations of its calorific value by the Berthier method gave 10,145 British Thermal units per pound.

The general results of the tests are given in table No. 1.

TABLE NO. 1.

GENERAL RESULTS.

| | UNITS. | TEST. | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Duration of test. | Hours | 12 | 24.00 | 9.00 |
| Equivalent water evaporated per pound of combustible from and at 212 deg. F. | Pounds | 7.81 | 8 | 8.22 |
| Percentage of total calorific power utilized by the boiler | Per cent. | 63.55 | 65.08 | 67.24 |
| Load factor. Average watts divided by maximum watts | Per cent. | | .87 | .82 |
| Water evaporated per net Kilowatt hour | Pounds | 51.4 | 46.09 | 40. |
| Coal burned per net Kilowatt hour | Pounds | 7.6 | 6.9 | 6.44 |
| Cost of coal per net Kilowatt hour | Dollars | .00722 | .00655 | .00611 |
| Electric'l energy on switch board per car mile | K. W. hours | | 1.37 | 1.63 |
| Coal per car mile | Pounds | | 9.45 | 10.50 |
| Cost of coal per car mile | Dollars | | .00897 | .00996 |
| Average number of cars on road | | | 9 | 9 |

Weight of cars with battery, 13½ tons.

Average speed of cars, not including stops, 12 miles per hour.

Average watt hour efficiency of batteries, 58 per cent.

We are now in a position to take up the question of the influence of the action of the different parts of the station equipment upon

the total plant efficiency. Take, for instance, the economizer which utilizes the latent heat of the waste flue gases. The percentage of gain (fuel saved) due to rise in the temperature of the feed water secured by the use of the economizer may be calculated as follows:

Let H = Total heat units in steam at boiler pressure reckoned from 0 degrees F. (Taken from steam tables).

T = Temperature of feed water after heating.

$t$ = temperature of feed water before heating. Then

$$\text{Gain per cent} = \frac{100\,(T-t)}{H-t}$$

In the first test the percentage of fuel saved as calculated by this formula was 7.4% and in the second test the result was 6.9%. It

Fig. B. Engine Generator Unit.

has been shown by numerous evaporative tests, that the actual saving due to an economizer is ordinarily about 30% greater than calculated by the above theoretical formula, so we are more than safe in taking the saving due to the economizer in this plant at 7%. During the third test the economizer was not used and it is instructive to notice the loss in this case between the heater and the boiler, which amounted to about 1%. With a coal bill of $7,000 per year it will be seen that at 7% the economizer saves $520 per year. In this case the economizer and extra flues required cost $3,000 or about $5 per boiler horse

power. The saving effected, then, represents an interest of 17.4% upon the investment which is enough above the usual allowance for interest and depreciation, to justify the purchase. It may be said that the economizer in this plant is not installed or operated to the best advantage and that in general the actual saving which may be effected by the use of this device will be about 10%. If in conjunction with the economizer a mechanical draft had been adopted for this plant a part of the 15% of the heat units in the coal which escaped in the flue gases passing up the chimney and which were necessary to produce the draft would have been saved and the total station efficiency would have been proportionately increased.

The top curve on Fig. 1, which shows the observations made upon

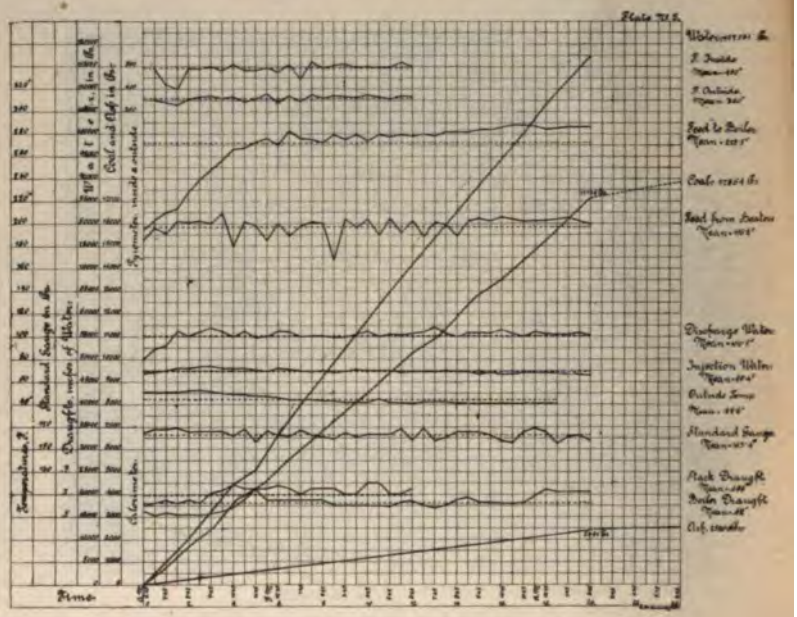


Fig. 1 Boiler Test No. 1.

the temperature of the feed water during the first test shows two points worth noting. The gradual rise in the beginning of the curve represents what might be called the "time lag" of the economizer, while the rise during the latter part of the test was due directly to the influence of a pipe covering which was at that time placed about the feed water pipes leading to and from the economizer. The average gain in the feed water temperature due to the covering may be taken as ten degrees and if we apply our formula as before we find a

resultant gain of 1%. Based on a coal bill of $7,000 per year this represents a saving of about $70 per year. The actual cost of the pipe covering in place was $64, thus showing a very good investment and it will be of value to note that this was upon the feed water line.

The pumps in the last test used 14.36 % of the water evaporated by the boilers. The feed water, however, was heated by the exhaust steam, from a temperature of 97.4 degrees F. to a temperature of 202 degrees F. resulting in a gain of $\frac{100(202 - 97.4)}{1196.5 - 32 - 97.4}$ or 9.25 %. The actual amount of fuel then to be charged up against the pumps is

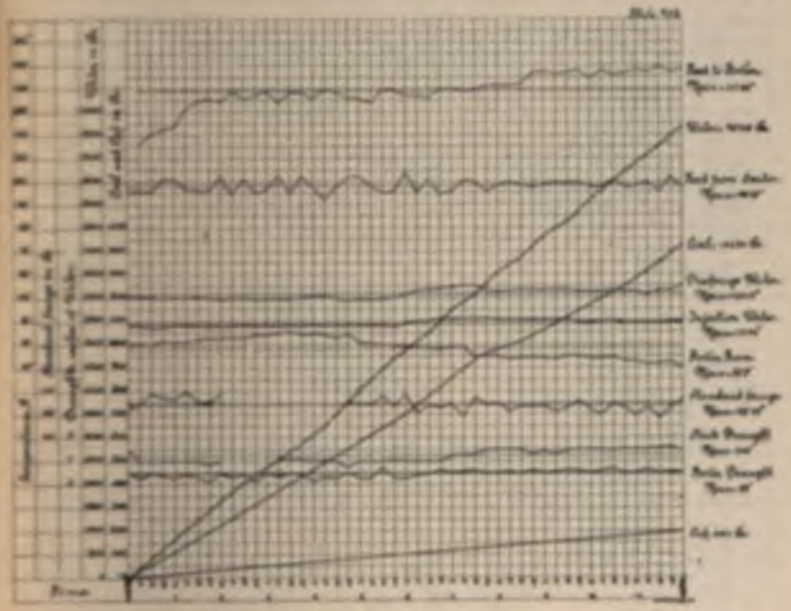


Fig. 2. Boiler Test No. 2.

only 14.36 % — 9.25 % or 5.11 % of the total fuel burned. It was determined that the pumps developed an indicated horse power hour on 67.5 pounds of water, but if they return to the system the heat units shown, they are equivalent to pumps returning nothing to the system using $\frac{(5.11 \times 67.5)}{14.36}$ or 24 pounds of water per indicated horse power hour in the steam cylinder. This means that if the pumps were driven directly from the main engine shaft they might have been operated on a duty of 18 pounds of water per horse power hour instead of at an equivalent of 24 pounds and thus a slight improvement in plant efficiency might have been effected. If instead of driving the

pumps directly from the engine shaft an electric motor had been used, then there would have been introduced between the main engine cylinder and the pump cylinder the transmission losses due to the engine, to the generator, and to the motor. The efficiency between the indicated horse power of the engine and the delivered output of the generator in the last test was found to average 80%. If the efficiency of the motor be taken at the same figure we find a transmission loss of 36% and our pumps, if electrically driven would require $\frac{18 \times 100}{64}$ or 28 pounds of water per horse power delivered to the pump cylinder.

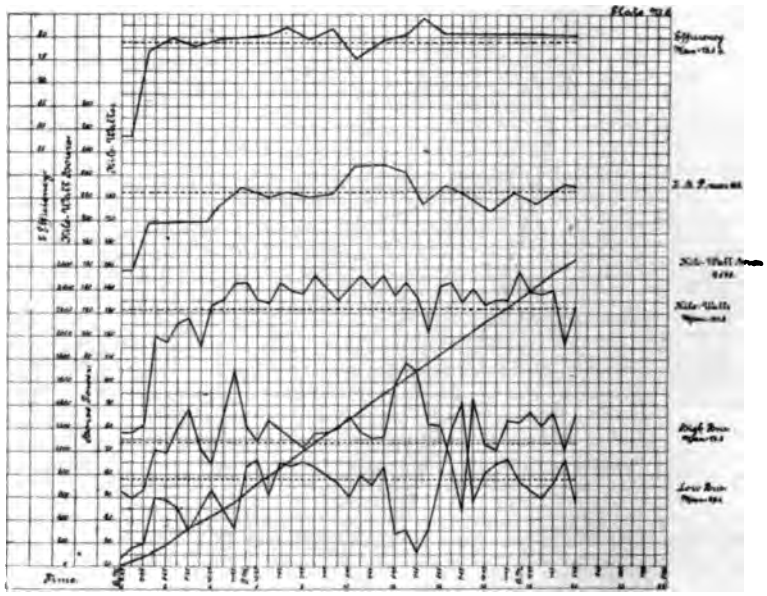


Fig. 3. Engine Test No. 2.

If we allow with our independent steam driven pump an efficiency of 85% between steam and water cylinders, our "equivalent" of 24 pounds per I. H. P. becomes 28 pounds per horse power hour delivered to the pump cylinder. The conclusion is that in a condensing plant with moderately efficient pumps using the latent heat of their exhaust to heat the feed water, but little economy, if any, can be gained by changing to the use of electrically driven auxiliaries.

The heat balance of the entire plant as worked out from all the data collected on the last test is shown in Table No. 2, and it will be

interesting to note where the original heat units in the coal go on their way from the coal pile to the switch board.

## TABLE NO. 2.

### HEAT BALANCE OF PLANT.

| | % HEAT UNITS USED | HEAT UNITS |
|---|---|---|
| *Boilers* | | |
| Loss by radiation, convection and draft | 21.7 | 2301 |
| Loss through incomplete combustion and in smoke | 13.44 | 1426 |
| *Engines* | | |
| Stoker Engine (very inefficient) | .97 | 99 |
| Air Pump | 2.61 | 267 |
| Feed Pump | .28 | 29 |
| *Condensation and Leakage* | | |
| Leakage and radiation in steam pipes | 2.10 | 213 |
| Loss by radiation in feed water line | .01 | 01 |
| *Engines* | | |
| Theoretical loss in engines | 44.20 | 4691 |
| Loss by radiation, condensation and leakage | 4.18 | 424 |
| Friction in engine and generator | 1.11 | 112 |
| *Generator* | | |
| Electrical losses | .44 | 45 |
| Power to drive fan of cooling tower | .12 | 12 |
| Delivered by switchboard | .93 | 95 |
| Total | 100.00% | 10614 |

One watt hour is equivalent to $\frac{1000 \times 60}{746 \times .778}$ or 3.413 B T U. If the original heat units in the fuel used by any station and the number of watt hours produced per pound of coal are known the efficiency of the plant may be at once determined by the formula

$$\text{Efficiency} = \frac{\text{Watt hours per lb of coal}}{\text{B T U per lb of coal}} \times .293$$

It will be instructive to compare the efficiency of other stations with the result of 5.58% obtained in the one tested. At first glance the efficiency of this plant may appear low but it will actually be found to be comparatively high and this is one of the great results of the high "load factor." The relatively high rate which can be maintained between the average load and the maximum load of the power station of an accumulator traction power station is one of the chief points which can be advanced in favor of this system and the practical value of the argument is shown very nicely both by the curves and the high plant efficiency. The tests further illustrate the

importance of keeping all the units in operation working, as nearly as possible, at their full rated capacity. This idea was demonstrated so thoroughly that the "three voltage" method of charging the batteries was abandoned during the use of a nine car schedule, and during the winter the plant has been run as operated in the third test. In the summer time, however, when the traffic is much heavier and two engines will be required to handle the load the original method of charging the batteries will again be adopted.

Some very interesting data on the cost of the cooling tower and condensing plant together with the amount of power required for their

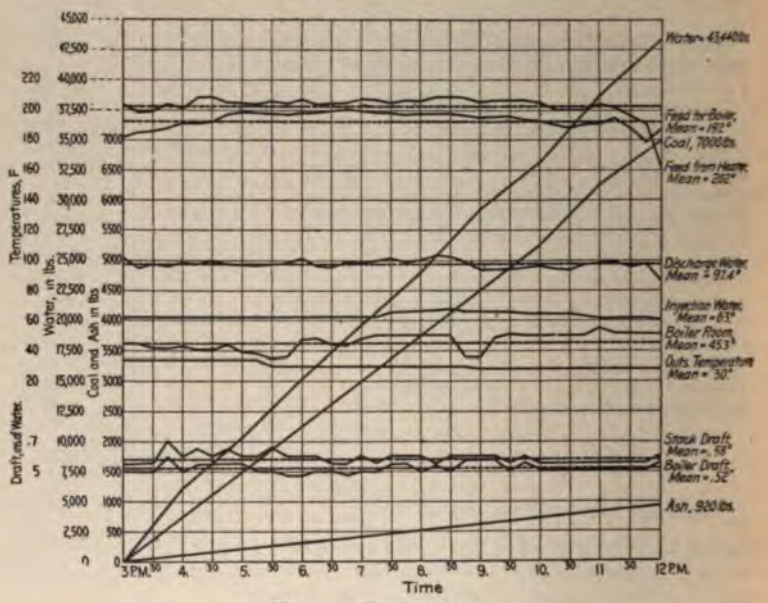

Temperatures, F.
Water, in lbs.
Coal and Ash in lbs.
Draft, ins of Water.
Water = 434400 lbs
Feed to Boiler, Mean = 192°
Coal, 7000 lbs
Feed from Heater, Mean = 282°
Discharge Water, Mean = 91.4°
Injection Water, Mean = 63°
Boiler Room, Mean = 45.3°
Outs. Temperature Mean = 30°
Stack Draft, Mean = .98
Boiler Draft, Mean = .52
Ash, 920 lbs
3 PM. 4. 5. 6. 7 8. 9. 10. 11 12 P.M.
Time

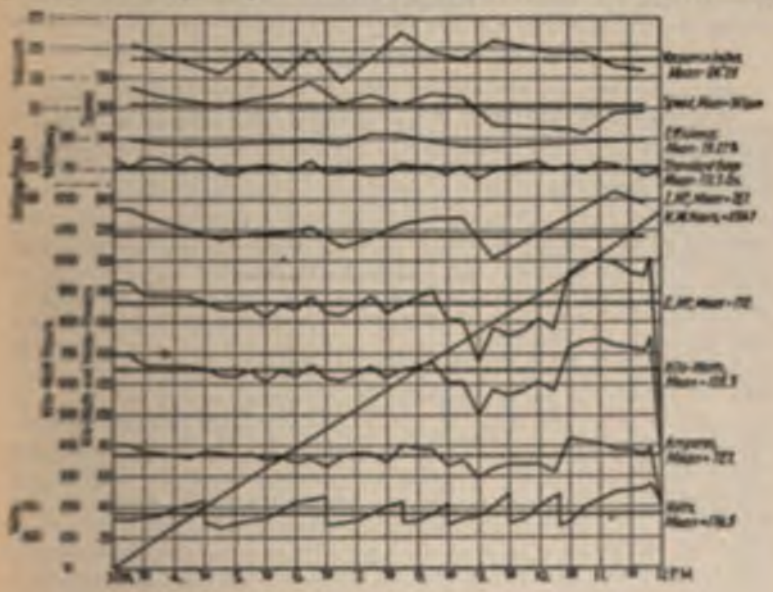
Fig. 4. Boiler Test No. 3.

operation is at hand and would make a valuable addition to the discussion as to whether or not it pays to install a "dry land" condensing plant, but lack of space will not allow its publication at this time. In this connection it may be stated that during the winter months the car barns and battery charging rooms are heated by means of the discharge water from the condensers, thus heating this large amount of space for practically nothing, and at the same time doing away with the use of the cooling tower.

The results of the first year's operation of this unique installation have been awaited by engineers with much interest. This road is the first one in this country to be fully equipped throughout for the purpose of operating storage battery cars exclusively. It may be said

that its success has been much greater than the most sanguine expectations of its promotors, and is such that even the most skeptical must be convinced of the success of accumulator traction. During the hard winter, just passed, the reliability of the service has been even better than that upon parallel trolley systems, while during the summer the carrying capacity of the cars are frequently overtaxed and thus the earning capacity of the road has been demonstrated.

The most surprising development of the whole scheme, however, has been the remarkable durability of the battery plates. During the year, just closing, forty-four batteries have traveled over 800,000 miles,



Time.

Fig. 5. Engine Test No 3.

and the only expense for maintenance has been for the small amount of labor required to occasionally clean the plates. Even if a large outlay were to be required at the end of the year to replace the positive plates the cost of maintenance would fall within a reasonable figure. As it is the batteries appear to be in the best of condition, and will apparently last many months, thus demonstrating the commercial utility of the system.

In regard to the commercial efficiency of the entire system it may be noted that it compares favorably with that of trolley roads operating under similar conditions. The cost for fuel of less than one cent per car mile falls well within what is considered good street rail-

way practice. The disadvantage of the apparently excessive loss between the switch board and the motor axle is balanced by the advantages that accrue from being able to operate the power station at a constant and efficient load for a shorter time each day than that during which the cars are running. As a whole, the operation of this road must be taken as a demonstration of the applicability of accumulator traction to street and suburban railway service.

## STRENGTH OF WROUGHT IRON AT LOW AND HIGH TEMPERATURES.

R. C. CARPENTER, '75.

Wrought iron and steel are frequently employed by mechanical engineers in locations or positions where the temperature varies a great amount from the normal, thus for the construction of steam boilers, wrought iron or steel is employed in positions where the temperature must certainly exceed that due to the pressure of the steam used and often reaches a temperature of from 300 to 500 degrees; in steam pipes and engines the temperature is essentially the same as that of the steam, though perhaps somewhat lower. The heating up of journals caused by lack of proper lubrication sometimes causes a very high temperature, and such conditions are not uncommon in respect to car axles or line shafting. On the other hand there has been an extensive use of material in refrigerating machines during the last few years, portions of which are subjected to extreme cold. These examples are sufficient to emphasize the fact that metals are frequently employed under such conditions of use as to be subjected to temperatures essentially different and either higher or lower than that of the air found in inhabitable locations; it is then a matter of practical importance to ascertain whether or not extreme temperature conditions have any material effect on the strength of such materials as would ordinarily be employed.

The results of the investigation which will be described in the latter portion of this paper indicate that the temperature has an important effect on the strength of the material, and that in regards to most materials, *i. e.*, either wrought iron or steel, the strength is practically a minimum at about 70 degrees Fahrenheit and increases as the temperature is changed in either direction, and becoming about 20 per cent. stronger at temperatures of about 500 degrees Fahrenheit on the one hand and 60 degrees below zero on the other. The law of increase of strength is shown graphically in diagram 4 accompanying this article. By consulting this it will be noted that the increase in strength is gradual but well marked as the temperature changes in either direction.

Besides the strength of metals an important consideration is that relating to their toughness or power to resist shock; this property is indicated in tension tests by the amount of elongation found within the elastic limit and up to the point of rupture. A study of this property indicates that the lowering of the temperature from 70 degrees to that of 60 below has little or no sensible effect on the ductility of the metal but that a considerable change is experienced by increasing the temperature. Our investigations of the strength of metals at high temperatures indicate a brittle region at the temperature of steam at 5 to 10 pounds pressure, and this same property has also been noted by a German investigator, from which it would seem that although the strength is increased the metal has less power to resist the effects of shocks at the ordinary temperature of steam than when at the usual temperature of the air.

CRYSTALLIZATION NOT COVERED BY CHANGE OF TEMPERATURE.

The subject of the cause of the crystallization of iron has been investigated so far as lay within our power by numerous experiments in the Sibley College laboratories, the attempt being made to produce crystallization by some method of applying stress. This subject does not properly come under the title of the present article, except so far as the effect of heat and cold in producing this phenomena was employed. The method of making these tests will be briefly stated to have consisted in the rupture of similar materials first by falling weights moving with greater or less rapidity, then by shocks caused by the explosion of gun powder and dynamite, then by breaking with blows after a repeated number of heatings and coolings and finally the application of a great number of blows of small intensity.

The general results of these investigations indicated that the statement which is made in nearly every text-book, relating to the strength of materials and even in some of the recent books on this subject, that crystallization could be produced by a rapidly applied blow was entirely erroneous; on the contrary the elongation was found to increase with the velocity of the blow; thus with the application of a static load a certain elongation was produced, by rupturing with a blow the elongation was increased, by rupturing with gun powder the elongation was still greater and with dynamite it was even greater yet. The effect of applying rapid blows or of rupturing with great rapidity had in no case the tendency to produce crystalline fracture. The effect of breaking after a large number of repeated heatings and coolings has been stated by some authorities to produce a crystalline fracture; but the results of a large number of experiments did not, however in any case show that such was the fact and the conclusion which the writer drew from these experiments were that crystallization was not caused by conditions due to changing temperature. It is admitted that the only evidence respecting this point is of a negative character, but it is believed that the experiments

covered more alterations of heat and cold than would be found in any practical case. The experiments in the line of a great number of blows of light intensity were more promising, and several cases of distinctly crystalline fracture were produced.

These experiments together with the fact that breaks showing crystalline fracture are almost invariably found where material is used in such manner as to be subjected to repeated shocks of small intensity, has led the writer to believe that crystalline fracture may be and is produced in material which is originally fibrous and of excellent quality by a repeated number of blows or shocks, any of which are of small intensity, but are repeated with great frequency. The effect of these blows or shocks being to cause a new arrangement of the molecules which constitute the fibers into a crystalline form and hence into such a position as to possess little tenacity or coherence.

This view is strengthened from the fact that nearly all the breaks which occur in lines or coupling pins used by railroads are distinctly crystalline and the rupture occurs without any reduction in the section of the metal or any elongation of the original material. In the service which causes these breaks there is an application of a repeated number of shocks of small intensity.

Some writers have contended that crystalline fracture was only found in material which was originally of bad quality and that the crystalline structure always existed in the material; this view the writer is certain is incorrect as he had experience with a machine in which repeated crystalline breaks occurred and these could not be prevented by the use of the very best quality of material, and material which was known to have been free from defects of any character.

In connection with crystalline breaks it will usually be found that the area affected by the crystalline action is at one section only of the material, and that all other portions of the material are perfectly fibrous and of essentially excellent quality. This naturally can be accounted for by the theory that the change in molecular arrangement is caused by vibration of the particles which would be maximum at a certain position or cross section of the material and would affect it in no other place.

With this preliminary and introductory statement, we will now consider the methods of experimenting and the results obtained when the test specimens were affected by temperatures essentially different from those under ordinary conditions.

During the past year a number of tests were made in the laboratories of Sibley College by the writer with assistance of R. E. Chandler, M. E., and L. L. Brinsmade, B. S., both graduate students, on the tensile strength of wrought iron at low temperatures.

The specimens selected were from uniform stock and were all turned to the size shown in the annexed sketch, Fig. 1. The test was made on an Emery testing machine of the horizontal type built by William Sellers & Co. The test pieces after being placed in position

were surrounded by a freezing mixture which was placed in a box fitted around the specimens, the box being several inches longer than the reduced portion of the specimen. Several clamps were attached to the specimen well within the box containing the freezing mixture,

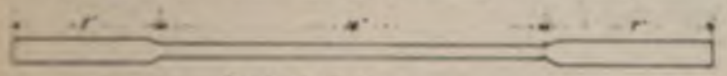


Fig 1 - Specimen

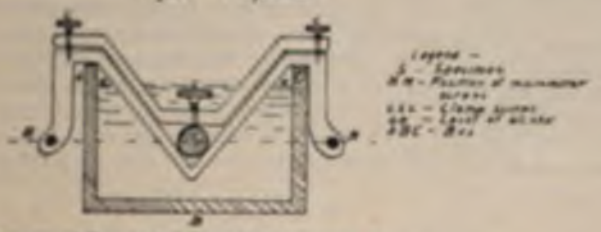


Fig 2 - Section of Box and Clamps for Micrometer Screws

and of such a form that the ends extended outside the specimen and gave an opportunity for measuring the extension with micrometer screws which were arranged parallel and equi-distance from the center of the specimen. The form of the box and clamps are shown in Fig. 2.

Considerable difficulty was found in obtaining a suitable freezing mixture. The first attempt was made to secure low temperature by means of the expansion of compressed air in some fluid that would not freeze, as for instance brine for the higher temperature and alcohol for the lower, but because of the lack of a suitable motor for transforming the heat of the air into work, but little reduction in temperature was secured by this method, and other means had to be employed.

It was found after considerable experiment that by surrounding the specimen with alcohol and by spraying liquid carbonic acid into this that it was possible to hold and maintain a temperature at any desired point as low as 70 *degrees* Fahrenheit below zero at pleasure. Tests were made showing the strength of the specimen within a range of temperature of 70 above to about 70 degrees below on the Fahr. scale.

The increase in strength due to diminution of temperature was frequently sufficient to cause the specimen to break in the larger cross-section near the ends of the specimen which was necessarily exposed at the temperature of the room. To overcome this tendency to break in the larger cross-section it was found necessary to reduce the area of cross-section near the center specimen more than originally intended.

The general results show first a decided increase in strength

[illegible]

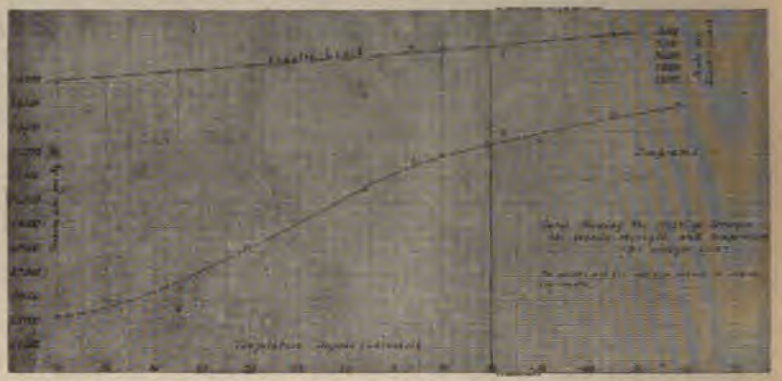
The tests of wrought iron at low temperatures seem to indicate that iron is not only stronger than at ordinary temperatures, but that it is equally ductile and hence under no circumstances more likely to be broken by suddenly applied shocks or blows. From the fact that iron railroad rails break more frequently at low temperatures than at high, it was formerly believed that iron at low temperatures was more brittle; this phenomena is probably to be explained, however, not by the increase of brittleness on the part of the iron, but by the increase in the severity of the shock caused by the rolling stock and wheels of the train impinging on the metal when in contact with the frozen ground. The latter condition is doubtless a favorable one to produce crystallization and it is quite reasonable to suppose that the increased number of breaks in extremely cold weather is due, not to increased brittleness of the metal, but to crystallization produced by a great number of severe blows.

| No. | Temperature Degrees Fah. | Diameter in inches. | Area in square inches. | Maximum load in Pounds. | Tensile strength in lbs. per sq. in. | Per cent of normal.* | Character of Fracture. | Area of Fracture in per cent of original area. | Elongation in eight inches. | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 70 | .498 | .1952 | 8800 | 45400 | | Cry. Course | 50. | 1.64 | |
| 2 | 70 | .500 | .1963 | 9150 | 46500 | | Crystaline | 45.4 | 1.98 | |
| 3 | 70 | .497 | .1940 | 8600 | 44300 | | Fibrous | 61.5 | 2.0 | |
| 4 | 45 | .495 | .1908 | 8700 | 45600 | | | 60.0 | 1.75 | |
| 5 | 32 | .495 | .1924 | 8900 | 46500 | | Cry. cup shape | 50.0 | 1.75 | |
| 6 | 32 | .495 | .1924 | 9000 | 46500 | | Cup shape | 48.0 | 1.60 | |
| 7 | 32 | .488 | .1868 | 8600 | 46000 | | Coarse Crys. | | 1.72 | |
| 8 | 32 | .488 | .1868 | 8700 | 46600 | | Cup shape | 49.0 | 1.6 | |
| 9 | 32 | .490 | .1885 | 8500 | 47100 | | Cup shape | 49.0 | 1.6 | |
| 10 | 10 | .501 | .1971 | 9900 | 50000 | | Cry. cup shape | 47.7 | | |
| 11 | 6 | .491 | .1893 | 8900 | 49000 | | Cup shape | 48.0 | 1.68 | |
| 12 | 6 | .491 | .1893 | 9800 | 51800 | | Cup shape | 48.0 | 1.7 | |
| 13 | 6 | .487 | .1862 | 10000 | 54500 | | Fibrous | 55 | 1.50 | |
| 14 | —4 | .501 | .1971 | 10200 | 51800 | | Fibrous | 50 | 1.75 | |
| 15 | —4 | .496 | .1932 | 10000 | 51800 | | Fibrous | 50 | 1.98 | |
| 16 | —10 | .500 | .1963 | 10200 | 52000 | | Fibrous | 51.5 | 1.79 | |
| 17 | —22 | .492 | .1901 | 10300 | 54000 | | Cup shape | 44.7 | 1.78 | |
| 18 | —22 | .491 | .1893 | 9800 | 51800 | | Cup shape | 65.0 | 1.75 | |
| 19 | —20 | .492 | .1901 | 10000 | 52500 | | Crystalline | 51.4 | 1.85 | |
| 20 | —20 | .492 | .1901 | 10000 | 52500 | | Crystalline | 50.5 | 1.75 | Broke 2 mk. |
| 21 | —45 | .485 | .1847 | 9800 | 53000 | | Coarse | 50 | 1.6 | |
| 22 | —45 | .491 | .1893 | 10300 | 754500 | | Cup shape | 48.2 | Broke 8" mk. | |
| 23 | —58 | .488 | .1870 | 10000 | 53500 | | Dark Cry. | 51 | 1.85 | |
| 24 | —58 | .470 | .1734 | 9500 | 54700 | | Cup shape gran | 51.5 | 1.25 | |

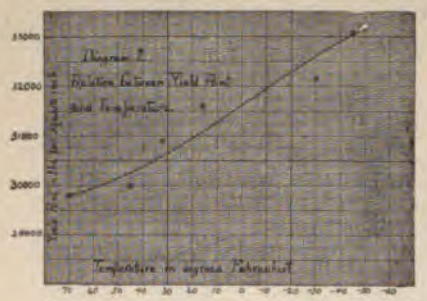
Per cent of Normal as in Curve.

The following diagrams show graphically the results of the various tests. Thus diagram 1 shows the increase in tensile strength with decrease in temperature. In this diagram the tension in pounds per square inch is taken as ordinates, the temperature in degrees

Fahr. as abscissa. On the same diagram is drawn a curve which shows the strength at the elastic limit with decrease in temperature.



This latter curve is not perfectly regular, but neglecting a single observation the results of all the test show a sensible rise in the elastic limit with decrease of temperature. The position of the elastic limit as shown in this diagram was obtained by carefully plotting all the observations and taking the position of the elastic limit as the point at which the deformations ceased to be proportional to the stresses.



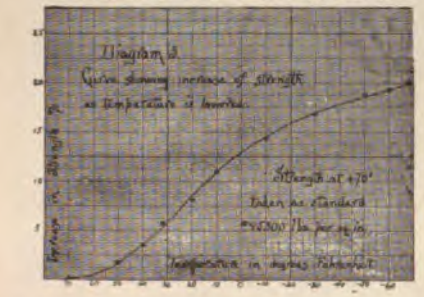



Diagram 3.
Curve showing increase of strength as temperature is lowered.
Strength at +70°
taken as standard
Temperature in degrees Fahrenheit.

Diagram 2 is interesting since it shows the relation of yield-point or what is frequently termed the commercial elastic limit to the load. In this case the yield point is defined as the point at which the first permanent set becomes visible due to settling of the scale beam. By comparing the two curves it will be noted that this latter quantity is somewhat above the true elastic limit, but the same law of increase of strength with reference to decrease of temperature applies.

Diagram 3, shows the curve of increase in strength plotted with reference to the strength at 70° F. as 100.

Diagram 4, is a combined diagram showing the results of the tests made both at low and at high temperatures. In constructing this

diagram in order to make it continuous the strengths of both series of tests were equalized at 70 degrees. This is an arbitrary assumption which may not be quite true, but its effect on the result would only be to raise the curve of strength for the higher temperatures slightly above the position shown. The test for the materials at high temperatures was made some years previously to that of the test with low materials and the nature of the stock used in the different tests seems to have been somewhat different, since the material tested at high temperatures was a few per cent stronger.

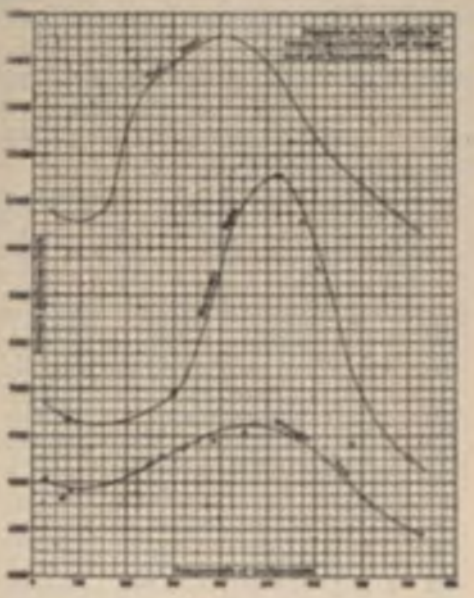


Diagram 5.

The stock used in both series of tests was as nearly uniform as possible and the uniformity of the results show very clearly the effect of cold and heat on the strength of the material. It cannot be claimed that the investigation is complete since it would be extremely interesting to test other materials under the same condition and also to determine the effect of varying the composition.

Following the curves of this series of tests are given the results of tests of wrought iron, machinery steel and tool steel at high temperatures. The similarity of the curves, for different materials, shows so far as the point of maximum and minimum is concerned, that the nature of the material has little effect on the general character of the relation of strength to change of temperature, and farther that the strength of materiai is affected to a great extent by the temperature.

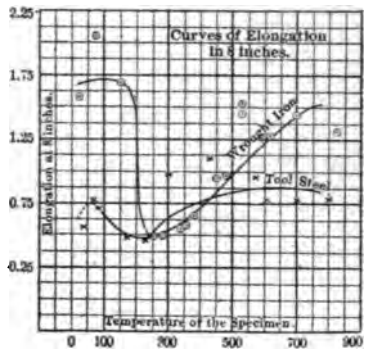



Diagram 6.

Diagram 6 shows the elongation in specimens 8 inches in length of wrought iron and tool steel at different temperatures from which it is noted that a minimum elongation is found at a temperature of about 250 degrees after which the elongation increases with the temperature.

RESULTS OF TESTS OF WROUGHT-IRON SPECIMENS AT HIGH TEMPERATURES.

| Temperature, Degrees Fahr. | Identifying Mark | Maximum Load, Pounds. | Diameter in Inche . | Area in Square Inches. | Tensile Strength, Pounds per Square In. | Per Cent. of Normal. | Elongation in 8 Inches. |
|---|---|---|---|---|---|---|---|
| | | | | | | | Inches |
| 23 | 2 | 9,900 | .4991 | .19555 | 50,500 | 103.0 | ..... |
| 25 | G | 10,300 | .5073 | .20210 | 50,980 | 103.8 | 1.63 |
| 82 | . | 9,300 | .4925 | .19051 | 48,820 | 100.0 | 2.10 |
| 150 | . . | 9,000 | .4815 | .18205 | 49,430 | 100.7 | 1.54 |
| 250 | H | 10,350 | .4935 | .19120 | 54,010 | 110.6 | ..... |
| 250 | J | 10,550 | .4956 | .19291 | 54,690 | 112.2 | .50 |
| 275 | 7 | 10,600 | .4906 | .18908 | 56,070 | 114.6 | .52 |
| 320 | 0 | 11,200 | .4934 | .19120 | 57,240 | 116 9 | .59 |
| 350 | I | 10,600 | .4791 | .18021 | 58,820 | 120.2 | .62 |
| 385 | D | 11,600 | .5003 | .19665 | 58,980 | 120.3 | .67 |
| 450 | A | 11,700 | .4986 | .19524 | 59,920 | 122.5 | .92 |
| 450 | 9 | 11,800 | .4964 | .19354 | 60,970 | 124.8 | ..... |
| 475 | + | 11,700 | .4878 | .18689 | 62,610 | 128.0 | .95 |
| 525 | E | 10,700 | .4667 | .17114 | 62,520 | 125.6 | 1.52 |
| 530 | 3 | 11,700 | .5001 | .19644 | 59,840 | 122.3 | 1.40 |
| 625 | 8 | 10,400 | .4931 | .19095 | 54,450 | 111.1 | 1.27 |
| 700 | C | 8,650 | .4855 | .18513 | 46,720 | 95.8 | 1.40 |
| 825 | F | 7,600 | .4960 | .19322 | 39,330 | 80.5 | 1.3 |

NOTE.—Normal is here taken as strength at 79 to 80 degrees Fahr.

## WROUGHT IRON.

| | | Fracture | | Appearance of Fracture | | |
|---|---|---|---|---|---|---|
| Area of Section Square Inches | Temperature of Bath Degrees Fahr. | Color | Character | Diameter before Fracture Inches | Area in Square Inches | Area of Fracture in Per Cent. of original Area |
| | | Normal | Silky | | | |
| | | " | " | | | |
| | | " | Fibrous | | | |
| | | Bluish | | | | |
| | | " | Silky | | | |
| | | | | | | |
| | | Normal | Silky Crystalline | | | |
| | | | | | | |
| | | | Silky and Crystalline | | | |
| | | | Silky | | | |
| | | Dark Bronze | | | | |
| | | Deep Purple | Fibrous | | | |
| | | Dk Pur Bronze | | | | |
| | | Dark Bronze | | | | |
| | | Dark Blue | Fibrous crystallized | | | |
| | | Blue Black | Silky | | | |

## RESULTS OF TEST OF TOOL STEEL SPECIMENS

| Identifying Mark | | | | | | Inches |
|---|---|---|---|---|---|---|
| | 0 | | | | | |
| | 0 | | | | | |
| | 0 | | | | | |
| | 0 | | | | | |
| | 0 | | | | | |
| | 0 | | | | | |
| | 0 | | | | | |
| | 0 | | | | | |
| | 0 | | | | | |
| | 0 | | | | | |
| | 0 | | | | | |
| | 0 | | | | | |

NOTE.—These specimens were hard and not of regular shape for remainder in this set for this reason these results are not printed.

B (1) signifies broke outside gauged length

## TOOL STEEL.

| Identifying Mark. | Temperature—Degrees Fahr. | FRACTURE. Color. | FRACTURE. Character. | AT POINT OF FRACTURE. Diameter in Inches. | Area in Square Inches. | Area of Fracture in Per Cent. of Original Area |
|---|---|---|---|---|---|---|
| . . . . 0 | 28 | Normal. | Gran. Flat. | .4756 | .1769 | 91.0 (?) |
| . : : : 0 | 73 | " | " " | .4540 | .1626 | 79.2 |
| 10 0 | 75 | " | Gran.& Crys.Flat. | .4214 | .1395 | 77.5 |
| N 0 | 75 | " | Gran. and Crys. | .4460 | .1562 | 84.0 |
| . . . 0 | 160 | " | " " | .4337 | .1477 | 77.0 |
| . . 0 | 230 | " | Gran. | .4394 | .1517 | 79.4 |
| 9 0 | 300 | " | Gran. and Crys. | .4436 | .1544 | 74.1 |
| 8 0 | 400 | Light Straw. | " " | .4905 | .1874 | 94.0 (?) |
| 3 0 | 425 | Dark Straw. | Silky. | .4327 | .1470 | 75.5 |
| : : : 0 | 560 | Blue Black. | " | 3870 | .1238 | 63.6 |
| 11 0 | 600 | Deep Blue. | Silky-necked. | .3400 | .0908 | 44.8 |
| 12 0 | 700 | " " | Silky. | .3693 | .1071 | 54.8 |
| : . : 0 | 825 | Blue Black. | Silky-nkd. & Crys. | .2830 | .0629 | 32.1 |

## RESULTS OF TESTS OF MACHINERY STEEL SPECIMENS.

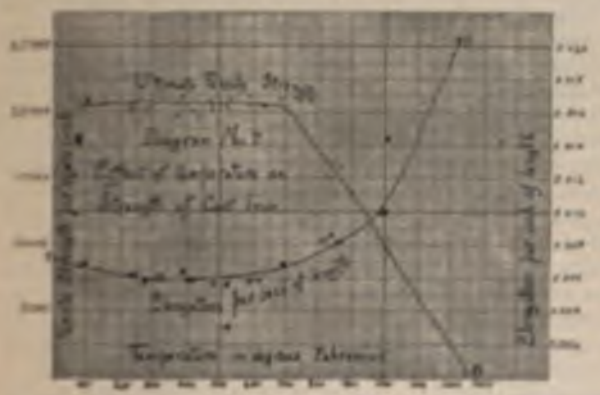
| Temperature—Degrees Fahr. | Identifying Mark. | Maximum Load—Pounds. | Diameter in Inches. | Area in Square Inches. | Tensile Strength—Pounds per Square Inch. | Per Cent. of Normal. | Elongation in 8 Inches. |
|---|---|---|---|---|---|---|---|
| | | | | | | | Inches. |
| 73 | X | 12,850 | .5073 | .2025 | 63,650 | 100.0 | 1.7 |
| 300 | 4 | 12,700 | .4853 | .1849 | 68,680 | 107.5 | .53 B. O. |
| 420 | 1 | 16,200 | .5120 | .2052 | 78,680 | 123.0 | B. O. |
| 525 | 5 | 23,400 | .5061 | .2011 | 116,370 | 183.0 | " |
| 575 | 6 | 19,650 | .4866 | .1860 | 105,660 | 166.5 | 1.02 |
| 680 | 2 | 10,500 | .4797 | .1807 | 58,120 | 91.4 | 1.22 |
| 800 | 7 | 10,400 | .4886 | .1875 | 55,460 | 87.1 | 1.42 |

## MACHINERY STEEL.

| Identifying Mark. | Temperature—Degrees Fahr. | FRACTURE. Color. | FRACTURE. Character. | AT POINT OF FRACTURE. Diameter in Inches. | Area in Square Inches. | Area of Fracture in Per Cent. of Original Area. |
|---|---|---|---|---|---|---|
| X | 73 | Normal. | Silky. | .3100 | .0757 | 37.5 |
| 4 | 300 | " | " | .3520 | .0973 | 52.5 |
| 1 | 425 | " | Silky-necked. | .3855 | .1166 | 57.1 |
| 5 | 525 | Dark Bronze. | Gran. and Crys. | .4395 | .1517 | 75.5 |
| 6 | 575 | Deep Purple. | Silky Well Nkd. | .2860 | .0628 | 33.7 |
| 2 | 675 | Deep Blue. | Silky Fine Crys. | .2740 | .0590 | 30.0 |
| 7 | 800 | " " | Silky Well Nkd. | .2665 | .0557 | 29.7 |

EFFECT OF TEMPERATURE ON THE STRENGTH OF CAST IRON.

A number of experiments have also been made to determine the ct of increasing the temperature on the strength of cast iron. results of these various tests are shown in diagram No. 7, in which abscissæ correspond to the temperature in degrees Fahrenheit, ordinates of the curve A B to the strength per sq. in. as shown on scale to the left, and the ordinates of the curve C D to the elon- on per inch of length, as shown on the scale to the right. The lts of each test is indicated by a point.



By study of the curves corresponding to these various tests it will oted that the tensile strength of cast iron remains uniform from mperature of 70° to that of nearly 700°, but from that point it de- ases in proportion to the increase of temperature until it becomes ctically nothing at a temperature of 1240°.

The elongation per inch in length seems to slightly decrease from mperature of 100 to 400 degrees after which it increases with in- se of temperature until the temperature of 1200 degrees is ched. The elongation of cast iron is exceedingly small under best ditions and hence this latter property is one of little importance ght as indicating a brittle region in the neighborhood of 300 or 400 rees.

# ON THE ETHICAL STATUS OF THE ENGINEERING PROFESSION.

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Ethics in a general sense is defined as "the science of right conduct and character: the science which treats of the nature and grounds of moral obligation and of the rules which ought to determine conduct in accordance with this obligation; the doctrine of man's duty in respect to himself and the rights of others."

In a more restricted sense, it is considered to be "a particular system of principles and rules concerning moral obligations and regard for the rights of others, whether true or false: rules of practice in respect to a single class of human actions and duties: as social ethics, medical ethics." Evidently, under the definition, these rules may be formulated, as in the codes of medical societies, the rules of courts and bar associations, the agreements of architects, the canons of the church; or they may, like the British Constitution, be so generally recognized that their formulation in definite statements is not necessary, and in the usages of good society. There is no formulated code for the engineering profession in any of its branches, and careful observation will fail to discover any distinctive body of ethical doctrine which is accepted by any large number of professed engineers. We will not now discuss directly the question of the desirability of or the objections to formulating such a code, but will consider the ethical basis of the profession from the standpoint of the more general definition.

The comprehensive definition of "profession" in the Century Dictionary, states that it is "the calling or occupation which one professes to understand and to follow; vocation: specifically a vocation in which a professed knowledge of some department of science or learning is used by its practical application to affairs of others, either in advising, guiding or teaching them, or in serving their interests or welfare in the practice of an art founded on it.

"Formerly, theology, law and medicine were specifically known as the professions, but as the applications of science and learning are extended to other departments of affairs, other vocations also receive the name. The word implies professed attainments in special knowledge, as distinguished from mere study or investigation; and an application of such knowledge to uses for others as a vocation, as distinguished from its pursuit for one's own purposes. In professions, strictly so-called, a preliminary examination as to qualifications is usually demanded by law or usage, and a license or other official authority founded thereon required. In law, the significance of the word has been contested under statutes imposing taxes on persons pursuing any 'occupation, trade or profession,' and under statutes au-

of evolution, and it may be both interesting and profitable to give briefly a few of the steps in their progress, that we may better understand their present condition and stage of development, and their relations to each other.

The three so-called learned professions were doubtless originally one, and were practiced by the priests, who were at the same time spiritual and temporal advisers and alleviators of bodily ills. This came naturally from the desire of man, even in the early stages of his civilization, to bring himself into unity with the higher power to which he considered himself to be subject. The priest was the mediator in this process, and, by analogy became the mediator between man and man in their frequent discords, and even between man and his own body, when a lack of unity in this relation brought about a condition of disease. Further development, and the accompanying differentiation of effort, finally separated the three and they have continued their respective courses of development in parallel lines. It has not been a century since these three were the only learned professions. The enormous intellectual development of civilized man and the resulting vast improvement in physical conditions have caused a large addition to the number of vocations in whice a "professed knowledge of some department of learning is used, by its practical application to affairs of others in advice, guidance or instruction, or in the practice of an art in their service." We are rapidly coming to the point where a change in the basis of classification of professions must be made. The original man had a very dim idea of what he was actually striving for, and his idea of unity was fairly well satisfied when his immediate disputes with his deity, his fellow man or his body were settled with some approach to fairness, so that the three professions have long held the positions of arbitrators in these primitive strivings for unity in their various fields. The world's idea of the meaning of unity is now vastly larger, and the basis of the classification must be correspondingly enlarged. We may divide the various professions, therefore, into three classes, similar to the former, having to do with the spiritual, the intellectual and the physical relations of man, but with the higher modern idea of unity as the governing principle. The most important professions in these three divisions are the religious leader, the teacher and the engineer. Such other professions as have an enduring basis can be assigned readily to one of these three classes by their most prominent characteristics.

As the philosopher and religious teacher and the guide in intellectual pursuits expand the spiritual and intellectual life, as the artists in various lines add to the appreciation of the various expressions of spiritual and intellectual power, so the engineer reduces to subjection the powers of nature and enlarges and beautifies the expression of man's power in the formation of his physical surroundings.

Evidently the engineer belongs to what is, strictly speaking, one of the most learned of the professions. He must not only be a man of high intellectual development and spiritual insight, but he must be able to apply his power to the training of the powers of nature. His profession requires quite as much preparation as do those which have for their object the training of the spiritual and intellectual powers of man. It is lower in estimation only by the amount that the process of subjection of physical forces to perform required offices is considered to be less valuable than the direct training of the powers of the human mind. It stands on a par with all those professions whose objects is the serving of the interests or welfare of our fellow men in the practice of arts founded on them.

How many of us recognise these facts and make our preparation for practice commensurate with the legitimate demands of our profession? In this broad light it is not sufficient to have learned the use of a few tools such as mathematics, and to have acquired a knowledge of a few sciences which will be of practical use in a narrow line, but it is essential that the view be broadened, the intellectual powers be developed in full, that a man may become a professional man, fit to "advise, guide and teach others and practice the arts founded on his profession;" and not sink to the level of a craftsman, who has only skill with his tools and can not grasp the large professional problems and offer adequate solutions.

In the early days the priests were few and took care to strengthen their power over their superstitious fellow men by many arts. As numbers increased and as civilization advanced, there came to be differences of opinion and divisions, which showed the awakening people that the priests were men like themselves. The instinct for self-preservation developed what might be called a system of professional ethics which was more complete and more thoroughly enforced than any system that has since been adopted. Many of the rules and customs, especially in the medical and legal professions, are relics or modifications of the ancient iron-clad systems, and doubtless owe much of their authority and validity to this fact. The newer professions do not have this body of ancient custom upon which to depend, and must base their ethical systems on broader grounds to have them accepted by modern thought. This is one of the reasons for the erroneous objection that is made by many to definite codes of professions.

Engineering as a profession is not a century old. Its founders were men self-educated or educated for other lines of effort, who were drawn into its field by the imperative demands of the times and of their own natures. They worked largely by empirical rules and received recognition as professional men with high honors from the public and their clients by sheer force of ability and character. As the vast scheme of material improvement developed, which, in a sense, they may be said to have inaugurated, the number of men

necessary to direct it rapidly increased, and special means of preparation for the work were demanded. Naturally the methods of training were at first largely based on the more mechanical side of the profession, and the demand for early completion of the preliminary course of preparation led to a restriction of study to the more directly practical lines. Further development and differentiation has tended to continue this limitation of the education of the engineer. The result is too great specialization, a narrowness of view which shuts off the view of the other branches of the profession and of the world, and magnifies the importance of the individual in his own eyes. An observed consequence is, that (with the exceptions due to unusual powers of mind) the great engineers are the men who have had no preliminary training for the profession, or had with it a considerable proportion of the old-fashioned classical education, or had exceptional opportunities for development by early contact with men and affairs.

Checks in the progress of material development throw many men, particularly those with little breadth of training, out of their fixed employment. The necessity of a livelihood causes them to exploit more promising fields or a defective moral training and a restricted view of their relations to the profession and to their fellows, leads them into devices for securing employment or money which are far from complying with their moral obligations and regard for the rights of others. The ignorance of employers and, in the case of public works, the exigencies of politics, are additional incentives for such men to violations of the principles of ethics. The first wrong steps are doubtless often due to a lack of knowledge of the ultimate consequences of an act. A thorough grounding in the ethical principles which must underlie all permanently successful dealings with our fellow men would prevent many such lapses.

These various steps in the development of the profession, and the practical neglect of the ethical element in engineering education for many years, had opened the way to the present unsatisfactory condition of the engineering profession in this regard. Instead of retaining the standing among the highest which it had when in the hands of the great men of the early part of the century, its general average is materially lowered, both in the opinion of the members of the profession and in that of the general public. Happily there are few branches of the engineering profession in which it can be said that the ethical standard is actually low, as yet. Those which come most closely in contact with municipal and other public work where politics, partisan or otherwise, has a considerable influence, show the greatest effect of the lowering tendency.

What is necessary to improve the situation? The most evident steps are first, a better appreciation of the necessity of adherence to moral principles among the members of the profession. This can be effected most quickly by the education of the new recruits, made

definite by concrete instruction in the class of problems likely to arise in practice. A broader view of life and a more varied preparation for professional work and for participation in the general work of the world will aid in this direction also. Even if he must begin his specific occupation a year or two later in life, the engineer will find that he has saved time and enormously enriched his life as well as increased his earning capacity. The second is a better appreciation of the value of the engineering profession among those who may have physical improvement of various kinds more or less directly under their control. This can be secured by the improvement of the individual engineer by the broader education suggested, and by some process of separating the sheep from the goats, so that the engineering profession may be saved the odium of failures and frauds perpetrated by those who can by no stretch of any imagination but their own be considered as engineers. Unfortunately, there are also some good technical engineers whose moral obliquities must continue to cast discredit upon the profession until we have a formulated ethical code by which they can be read out of the profession. Whether we shall adopt such a code seems at present to depend upon those who are willing to suffer in silence, those who are not in positions where they are affected seriously by unprofessional conduct of their fellows, and those who think a code would not be advantageous to their individual interests.

In parenthesis let me say definitely what is inferred throughout, that our discussion is mainly in regard to the ethical principles of the action of professional men in the highest sense, those who "advise, guide or teach their fellow men by the use of their profession," and that, while the same principles apply throughout all ranks of the profession, those who are occupying semi-professional positions under the direction and pay of their fellows, or who are engaged in the more mechanical branches, are less directly affected by the wrong actions of other engineers and see less of the deleterious effects of competition, unrestricted by the power of clients to discriminate, or by requirements of technical ability or professional honor.

The hostility of such members of the American Society of Civil Engineers as attend annual meetings to any formulation of regulations of practice, and even to discussion of the question is shown by the prompt manner in which any resolution on the subject is laid on the table. At the last annual meeting a resolution favoring judicious legal restrictions of the use of the title Civil Engineer was so treated, one member resorting to the specious claim that it was an expression of opinion, which is forbidden by the constitution. An eminent engineer, whose preliminary preparation was for the practice of law inquired if it would be necessary for him to take up the practice of that profession, since he had been admitted to the bar, and had not received the degree of Civil Engineer. He forgot entirely that his admission to the bar was a process, technically at least, independent

of his receipt of a degree from the college of law, and that admission to the profession of Civli Engineering, under the resolution, would be equally independent of graduation from a technical school. It is true also, as he doubtless knows, that there are lawyers as prominent in their profession as he is in his, who are quite as innocent of experience in a law school as he is of attendance at a school of engineering.

The president of the society last year, an officer in the Corps of Engineers of the United States Army, gave a short and strong presentation of his argument against codes of professional ethics and protective legislation. In brief it is,—Education will remove the necessity for the latter and an application of the Golden Rule, "which is specially desirable in the engineering profession," will make the former unnecessary. Let the engineers and the people take their hard knocks until they learn these two lessons. Fortunately for the president, he is not in a position where any of the hard knocks which should reach the misdemeanants can reach him, as they do reach many equally earnest and honest men who do try to practice the Golden Rule. Numerous capable and honest men are annually driven from the profession by their dislike of meeting the unfair competition which they find and the low prices which self-styled engineers, and even some good engineers are willing to make to secure work. Better pay and pleasanter surroundings lead them away from a profession so loosely held together and subject to such ruinous competition. Their withdrawal causes a lowering of the average tone of the profession. In municipal and other public work the change of officers renders it impossible for education to have any effect. If a man does learn, it has been at many dollars expense to his constituents, and by the time he has learned he is displaced and the educational process must begin anew. Few politicians can be accused of applying the Golden Rule extensively. President Harrod's processes both fail in this case. In some cases in the government service they both apply. There are all gradations between the two extremes.

The foregoing is a statement of the problem in part from both sides. What decision will the reader reach as to the process of solution? Is it not the imperative duty of every engineer to himself and to the profession which he has chosen to make a thorough study of all possible phases and to determine the ethical basis upon which he will rest his personal practice?

Thorough study, observation and experience will show beyond a doubt that the highest professional success and a lasting reputation, professionally and personally, can only be attained by strict adherence to the principles of ethics in the fullest sense of the definition given. It will also show that uniform success in the lower walks of the profession, and personal happiness in one's work is dependent directly upon the right choice of the motive principles of his life. The effect of a bad start can sometimes be overcome by later efforts, but

the only career which is entirely satisfactory, is one which is right from beginning to end. Be sure to start right.

The question of the amount of aid which shall be given to the weaker brethren, and the amount of protection which shall be given to the rank and file of competent, honest men who seem to be much in need of it under the present conditions among our clients, is one which the young men, just entering the profession will probably have to decide. The nature of this aid and protection, whether by legal enactments or close professional organization, or both will in large part be determined by them, because the indications are that the conditions will demand some action by the time they have attained the positions of influence in the profession.

But, no matter what the decision on this subject may be, each one must look out for his personal standing, and not be led off by the apparently brilliant successes of some who seem to be deviating from the straight and narrow way. The success is only apparent, or it is followed by its legitimate consequence, a disastrous downfall. The brilliant operator may even succeed in amassing a fortune by his illegitimate methods, but it is at the expense of all else that makes life a real success.

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## THE YARYAN HEATING SYSTEM, PLANT NO. 2.

ABSTRACT OF THESIS OF RALPH COLLAMORE AND CHAS. O. COOK, 1897.

The heating plants operated by Mr. Yaryan in Toledo are essentially hot water systems. The water heated to a temperature, say 150° to 220°, is pumped through well insulated mains at a pressure sufficient to insure a rapid circulation throughout the system. This water is heated by the exhaust steam from the engines and the pumps in the plant, and when there is not sufficient exhaust steam, the temperature of the water is raised in a boiler through which it passes. This boiler is in use while the lighting engines are not running.

The test was made at the Yaryan heating plant No. 2, February 19th and 20th, 1897. This plant is located in the square formed by Fist, 22nd, and Madison Streets, and Park Place, Toledo, Ohio. The building is a one story brick structure 45 ft. by 72 ft.; the boiler and engine rooms each occupying about half of it. The engine room equipment is as follows:—A Smith's Dixie blower made by the American Blower Co. of Detroit, and used to produce a forced draught in the boilers; a 5 inch by 7 inch balanced valve Erie engine used to run the blower; one Deane (Holyoke) direct acting pump, 16 inch by 14 inch by 24 inches, and two Hughes duplex pumps, 8 inch by 6 inch by 12 inches, used to pump the hot water through the heating mains; a Yaryan condenser containing 1000 square feet of heating surface; a

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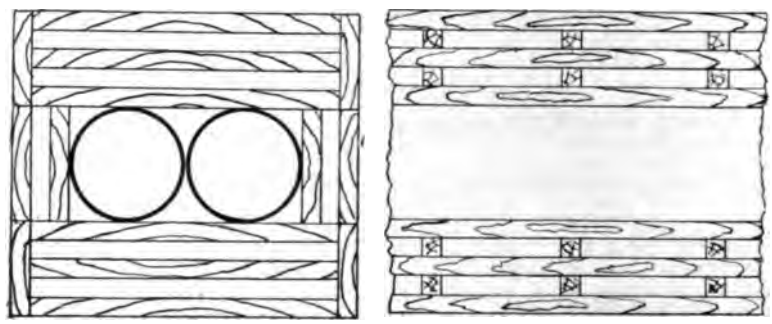
Yaryan oil separator and two Thompson-Ryan dynamos, 50 and 100 K. W., direct connected to McEwan engines, 11 inch by 12 inches and 16 inch by 16 inch. In the fire room are four tubular boilers, 72 inch by 16 feet, each containing 90 3½ inch tubes. Two of the boilers are used for steam, one for heating water for the heating system, while the fourth is kept in reserve. The furnaces are of the Dutch oven type, fired by the Jones underfeed stokers. The boilers are fed by a Marsh pump which draws the feed water from a hot well connected with the condenser. Just outside the building is an expansive tank for the heating system 12 feet in diameter and 10 feet high. The chimney is hexagonal, being 60 feet high with least diameter of 4 feet 4 inches.

The heating part of the plant consists of a heater (or condenser), a hot water boiler, pumps and the outside piping. The mains consist of two pipes side by side, one conveying the outgoing and the other the incoming water. These pipes are insulated with common one inch boards so arranged as to form air spaces as shown in the accompanying diagram. This insulation covers all the piping except the



Pipe Insulation.

expansion joints which are 6 feet Us. The piping consists of 1,520 feet of 6 inch, 13,280 feet of 4 inch and 1,800 feet of 3 inch pipe, which are laid in a ditch three feet deep. The service pipes are 1¼ inch. The water enters the pump from the expansion tank is forced into the heater, from there through the hot water boiler and then into the outgoing main. During the test the hot water boiler was not in use, while the dynamos were running as then there was enough exhaust steam to heat the water.

When the dynamos were not running the heat imparted to the water by the heater and by the hot water boiler was found iu the following manner: The calculation is based on the time from 9:25 P. M. on the 19th, to 4:00 P. M. on the 20th, 18½ hours, during which time the dynamos were not running. The amount of water that went through the pumps was known approximately by the stroke displacement.

its rise in temperature was also known. The number of heat units imparted to the water by the boiler was known (the efficiency of the hot water boiler was taken the same as that of the steam boilers), and hence the difference between the heat units in the water that went through the pump, and the number of heat units imparted to the water by the boiler gives the number of heat units imparted by the heater. Allowing 3% slip 19,165 gallons were pumped per hour.

19165 × 18,¼ = 356,181 gals. = 47585.7 cu. ft.

Average temperature incoming water = 141.9°.

Average temperature outgoing water = 171.3°.

A cu. ft. of water at 141.9° weighs 61.34 lbs.

47585.7 × 61.34 = 2,918,906.8 lbs. sent through the system in 18,¼ hours. This was raised 29.4° (171.3° −141.9°).

2,918,906.8 × 29.4° = 85,815,859 heat units in the water going through pump.

The heat units in the Hocking coal used was found to be 10,900.

3927.5 lbs. coal burned—This contained 6.75% moisture leaving 3661 lbs. of dry coal. The efficiency of the boiler was 74% and hence only 74% of 4097 pounds or 3468.3 pounds were available.

3468.3 × 10900 = 37,804,470 heat units given to the water by the boiler.

85,815,859 — 37,804,470 = 48,011,389 heat units received by the water in the heater.

As the amount of condensation was known as was also the temperature of the hot water as it entered and left the heater, the heat units received in the heater were determined from this data as a check upon the other method. The efficiency of the heater was assumed to be 75%. This gave about the same result as the first method.

On the morning of February 21st the temperature of the water was taken at the plant, and at several houses on the system in order to find the drop in the mains. The temperature at the plant was 170° F. At a house 1,320 feet from the plant the temperature was 161.5° F., here the water was throttled. At another house 1,220 feet distant the temperature was 166.5° with the valves wide open. Taking the latter as a fair working value the difference is 3.5° F. giving a drop of about 15° F. per mile. Assuming that the houses are at an average distance of one quarter of a mile from the plant, the heat loss in the mains amounts to 11.9 per cent., which brings the heating efficiency of the system to about 55 per cent.

This plant is connected with the old system (or first plant) and there was a certain leakage, but this was found to be comparatively small.

There are 37 houses heated, using a total radiating surface of 32,700 square feet. This is based upon a heating ratio of 30 to 1 for zero weather. The farthest house is at a distance of 2,300 feet from the plant. These houses are heated by either direct or indirect radiation. In some cases where steam heat has been used the hot water

pipes are connected to the steam pipes. Where hot air furnaces have been used it is possible to supplant the furnaces by coils of hot water pipes.

From a pamphlet describing the Yaryan Heating Process the following is taken.

"The plant herein described is essentially a hot water system, using the by product for producing lights. The result is interesting, as it shows that the sale of his by-product, *i. e.*, electric lights, brings an income sufficient to pay *all* expenses, including fuel, labor, etc., leaving the entire revenue derived from the sale of heat as his profit. His charges for the use of heat have been based upon the former cost of coal, in all cases. Thus it is clearly proven that a central station can furnish heat to the user at the same price he can produce it himself, thus avoiding all vexations incident to do domestic heating; no coal to handle, no ashes to remove, no dust to annoy the careful housewife, a uniform temperature at all hours of day and night, no danger from fire, and the central station, from the sale of its by-product, pays all the cost of producing the heat so distributed, and retains for a profit all the receipts from sale of heat."

This statement is also made. "A charge of $3.50 to $4.00 per 1000 cubic feet heated for the season in which heat is required, averages about the cost of hard coal for the same service."

The coal cost of 1,000,000 B. T. U. delivered to the residences is about 9.6 cents.

The following table is given to show comparison of the more important of the tests. Two coals were used during the run, namely. Hocking Drift and Jackson Lump and Slack.

| | With Hocking Slack Coal. | With Jackson Lump Coal. |
|---|---|---|
| Duration of trial, hours | 21.5 | 6 |
| Steam pressure in boiler by gauge, lbs. | 61 | 75 8 |
| Temperature of escaping gases, degrees | 346.3 | 331 6 |
| Temperature of feed water, degrees | 141.67 | 16.1 |
| Moisture in coal, per cent | 6.73 | 2 04 |
| Water actually evaporated per pound of dry coal from actual temperature and pressure, pounds | 7.57 | 8.0 |
| Equivalent water evaporated per pound of dry coal frem and at 212 degrees F., pounds | 8 | 10.28 |
| Equivalent water evaporated per pound of combustible from and at 212 degrees F., pounds | 9 | 11.1 |
| Equivalent water evaporated per pound of dry coal with one-sixth the refuse, at 70 lbs. gauge pressure from a temperature of 100° F., pounds | 6.53 | 8 |

[illegible] a horse power on a basis of 30 [illegible] of water per hour evaporated from a temperature of 100° F. into steam of 70 lbs. gage pressure

| | | |
|---|---|---|
| | 114.2 | 107.6 |
| [illegible] | 2.91 | 2.91 |
| [illegible] | 48.1 | 51 |
| Per cent. of heat transmitted to water | 74 | 74 |
| [illegible] evaporated 100° per cubic foot of water | 8.11 lbs. | 8.11 lbs. |
| [illegible] per pound of coal | 21.8 | 22.1 |

In the data tabulated [illegible] the following averages are arrived at:

| | With Hissing Coal | With Non-Hissing Coal |
|---|---|---|
| [illegible] | 99.2 | 97.6 |
| [illegible] | 71.8 | 81.4 |
| [illegible] | 50.2 | 65.4 |
| [illegible] | 141.6 | 161 |
| [illegible] | 170.6 | 176.2 |
| [illegible] | 141.1 | 164.4 |
| [illegible] | 160.1 | 181.7 |
| [illegible] | 81.1 lbs. | 9.1 lbs. |
| [illegible] | 6.2 lbs. | 8.4 lbs. |
| | 72 | 79.2 |
| [illegible] | 11.22 | |

[illegible] per cent. higher [illegible] with coal that was used [illegible] water heater.

## ELECTRICAL CONDUIT CONSTRUCTION

By H. [illegible]

[illegible] of the advantages to manufacturers of large electric power [illegible] use of electric motors for the distribution of electric current for light and power [illegible] has resulted in the construction of extensive underground conduit systems [illegible] of the principal cities of the country. In the construction of these systems [illegible] to be laid [illegible] and [illegible] the work.

[illegible] the preceding pages of this book for the construction of conduit systems, it may be well to make a few statements concerning systems with which we have been connected in the past.

The standard pumping equipment for the first section of duct work consisted of [illegible] air compressor, capable of delivering about 4 cubic feet of free air per minute, against a pressure of 100 pounds per square inch. A 1-inch galvanized iron pipe was laid from the compressor to the farthest manhole of the section to be built, and at intervals of about 1,000 feet along the line [illegible] were inserted in the pipe. To these [illegible] were attached lengths of rubber hose, which were carried into the manholes. [illegible] 1,000 feet of pumping hose were used by the company, but in some instances [illegible]

A conduit called the Ihlenfeldt from the name of the man who invented it has been used to some extent. In Fig. 1 on the right, an [illegible]

seen a piece of this conduit broken and projecting from the earth, several cables running out of the ducts. It was made in solid lengths of 3 feet each, having a sort of bell end for joining and was composed of a mixture of tar and asphalt. Seven to ten holes ran through this cylindrical block, which formed the ducts. The whole block was about a foot in diameter. and the ducts from two to three inches.

Fig. 1.

This form of conduit was not found to be very satisfactory as the joints would settle and break. 308,000 feet have been laid.

The Edison tube system, though not exactly a conduit, may be considered in this connection. This system has been used very extensively and consists essentially of a series of tubes or iron pipes enclosing three copper wires surrounded by a specially prepared compound. The ends of the tubes are joined in the manner shown in the cut and enclosed in a coupling box which is also filled with the compound. The lengths of tube are 20 feet each and have a diameter of from 1¼ to 3 inches. The larger size of tubes are used as feeders to carry the current from the power plant to junction boxes which are

trally located at the street corners. From these junction boxes current is distributed into mains which are the smaller sized tubes from these the services are tapped.

FLUSH BOX

BRANCH "T"

END BOX

STRAIGHT LINE BOX.

The tubes are laid bare in the earth about 2' or 2' 6" below the ace, and consequently the first cost of construction is much less that of the more modern systems of conduit. The maintenance ver is very much more expensive on account of short circuits burn-outs in wet weather. These are constantly occurring as r will work its way into the coupling boxes and one or more s of tube are frequently burnt their entire length.

The only way to repair the damage is to locate the trouble be- n junction boxes and dig for it, and it is often necessary to ex- te 50 to 60 feet before the burnt out portion can be found. constant tearing up of the streets is both costly and annoying, consequently, although 500,000 feet of tubing has been laid up to resent time, it is fast being abandoned or torn out and replaced e more modern system of conduit which will now be described.

This system consists of pipes or ducts surrounded by concrete en- g brick manholes or vaults which are built from 300 to 500 feet t usually at street intersections and in the middle of long blocks. l distribution holes are built between from 50 to 100 feet apart he purpose of running services off the main line into buildings.

Various kinds of ducts are used for the conduit, among them be- ement lined, tile and all-cement pipes. The cement lined pipes nufactured by the National Conduit and Cable Co., of New York, nside of cement about ¼ inch thick, inclosed in a sheet iron cover

ing which is securely rivetted around the cement, thus protecting it from damage in transit, and also in laying. The ends of the pipes are provided with a male and female joint. The pipes are made 8 feet long and about 3 inches in inside diameter. About 326,000 duct feet of this class of conduit have been laid.

The Camp tile is used quite a good deal and makes a nice conduit. It is simply a vitrified tile pipe manufactured in lengths of about 18 inches, and about 4 inches square on the outside, and 3 inches inside diameter. The lengths being short require many more joints and consequently more time in laying a given length, thus rendering it more expensive than the laying of the cement lined or cement pipe. The company has 195,000 duct feet of tile conduit.

An all-cement pipe manufactured in Chicago is used to a considerable extent, one advantage claimed for it being that when surrounded by material such as it is made of it forms a block of concrete as it were with the ducts running through it. The ends of the pipes are placed abutting squarely against each other and the inside surfaces brought into continuity by means of a sort of rubber spool about 4 inches long on the end of a rod called a mandrel. These spools are a little larger than the diameter of the pipe in the middle and taper down each way so that when the pipes are abutted and shoved tightly together they are sure to have their inside surfaces continuous. This method of laying takes more time than the cement lined pipes with their male and female joints require, but if done properly, is about as satisfactory. 316,000 duct feet of this conduit are in use at present.

At street intersections where many pipes are liable to come together, it is sometimes impracticable to lay cement pipes and concrete in the usual way to be described hereafter. In cases of this kind it is found to be more expeditious to use wrought iron pipe about 3 inches in diameter and in lengths of about 20 feet, with coupling and threads on each end. Any desired length can thus be coupled up and shoved through small openings or over or under a net-work of obstructing pipes where it were impossible to properly place and tamp concrete. Over 226,000 feet of iron pipe is thus buried in street intersections and difficult places about the city.

The method of laying the ducts is as follows:—A trench of the proper width depending upon the number of pipes to be laid abreast is dug generally from 3 to 4 feet 6 inches deep. The depth is governed by the number of pipes to be laid in height, and also depends upon the obstructions met, some of which are gas pipes, water mains, telephone and telegraph conduits, sewers, etc. In Figs. 1 and 2 several pipes of various sizes may be seen, as well as some conduit surrounded by concrete running directly across the excavation for an Edison manhole. It is often necessary to take these pipes into the manholes, building the walls around them. It is desirable to have at least 2 feet 6 inches of earth on top of the finished conduit in order that the pressure may be distributed and thus not cause conduit to settle or crack. The

pes are laid on a grade of about 2 inches per 100 feet at least, ough a much steeper grade is frequently necessary in order to get er or under obstructions. A summit may be made in the middle of block between two manholes, or the grade may be run all one way, e principal object being to avoid abrupt changes which cause fric- n in pulling cables through the pipes. For the same reason curves alignment are avoided except in cases of absolute necessity.

When the grade has been established and the trench trained up perly, 3 inches of concrete is placed in the bottom of the ditch d well rammed. Then a layer of pipe is put in leaving ¼ inch be- ween adjoining pipes into which fine concrete is rammed, 3 inches is mmed on each side of the pipes, another layer of pipes put in and on until the required number are in, when 3 inches of concrete is aced on top and the trench filled in.

FIG. 2.

The concrete is mixed in the proportion of one part cement to two sand and three of crushed stone. American Portland cement is ed, the Atlas or Star being the brands used most. The ducts are

built into the manholes in the manner shown in Fig. 2, a pocket being made into the brickwork to render the training of cables around the walls more efficacious. The manholes vary in size from 5 to 6 feet square for small ones, while some are as large as 10 × 15 feet. Often subways are built the whole width of streets, from curb to curb where a large number of cables have to be used. The walls of the manholes are usually 8 inches thick, except very large holes which have a 12 inch wall. In building the roofs, eye beams are used of a depth suitable for the width of span.

In holes under 6 feet in span, 3 or 4 inch tee iron is used, spaced about 9 inches apart to allow brick to be placed lengthwise between them. In holes from 8 to 9 feet and over it is more economical to build an arched roof thus economizing iron.

The question is frequently asked by those not familiar with conduit work, as to how the cables are gotten into the ducts when once they are laid. This is a very simple matter when understood. A number of wooden rods about ½ inch in diameter and 3 feet long, with a hook and eye on opposite ends are shoved through a duct by joining one after the other together. When enough rods have been shoved through from one manhole to reach another, say a block away, a man in the second manhole begins uncoupling the rods and pulling the remaining ones through and with them a small wire or rope which has been attached to the last rod coupled on in the first hole. When the wire or rope has been pulled through, the cable is attached and pulled from one hole to the other. When heavy cable is to be pulled as for instance, that having an area of 1,000,000 or 1,500,000 circular mils, a capstan is usually placed opposite the mouth of the hole on the surface of the street and a number of men wind the rope up on the drum of the capstan, thus pulling the cable which is unwound and fed from a large reel revolving on an axle at the other manhole. In this way cable is pulled several blocks until the weight becomes too great to pull conveniently, when another piece is started at the hole where the first piece is ended, and pulled as far as desired, and so on, joints between the ends of the cables being made in the manholes.

This company has been constructing conduits for about six years, and a general summary of the system owned by them is as follows:—

Total conduit of all kinds, 1,684,000 duct feet.

Total conduit of all kinds, 283,700 trench feet.

Total length of cable in ducts, 2,000,000 lineal feet.

Total number of manholes, 1,400.

## EDITORIALS.

We have endeavored to follow the example set by last year's [illegible] getting out our TECHNIC several weeks before Commencement. That we have been able to do through the promptness with which [illegible] responded. We wish to take this opportunity of thanking them for the interest they have shown in our annual [illegible]

* * *

The Engineering Alumni of Chicago have inaugurated a custom which is of great value to the Engineering Department and the Engineering Society. We refer to the first annual banquet of the Engineering Alumni of Chicago, held Saturday evening, May 14 1898. A large [illegible] of our graduates were present and report a great [illegible] the good work going on.

* * *

The TECHNIC is indebted to Prof. C. O. Taylor for photographs of the [illegible] of the new lighting plant.

* * *

The Engineering Society is indebted to T. Johnston '98 for a [illegible] illustrating a Wyoming Irrigation System, and to H. Fleming '98 for the thirteenth annual report of the Boston Transit Commission.

* * *

The month's tour of inspection taken this spring under the charge of John R. Allen was one of the most important events in the history of our department this year. The boys report a highly instructive and pleasant time.

* * *

We wish to ask our readers not to forget our advertisers from whom a share of the credit is due for this issue as well as former issues of the TECHNIC.

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THE TECHNIC had the camera and tripod out one day to photograph the [illegible] of the progress of work on a contract. They said that a photograph would give a more definite idea than the longest written report. Photographs contain, the data as to number of men employed, state of weather, etc. We receive an idea from most work a [illegible] number of men would cover the time.

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## EXCHANGES.

The Engineering Society regularly receives the following periodicals which may be found upon the tables in the Engineering Library and Reading Room.

WEEKLY.—American Machinist, Age of Steel, Engineering News, Engineering Record, Electrical Engineer, Electrical World, Railroad Gazette, Railway Review, Scientific American and Supplement, and Western Electrician.

MONTHLY.—American Electrician, Brick, Cassier's Magazine, Engineering Magazine, Journal of Western Engineering Society, Journal of Association of Engineering Societies, Journal of American Engineering Society, Journal of American Institute of Civil Engineers, Journal of Engineering Society of Western Pennsylvania, Municipal Engineering, and Street Railway Review.

QUARTERLY and other periodicals.—Alabama Geological Survey Reports, American Society of Irrigation Engineers, Digest of Physical Tests, Engineer, University of Wisconsin Bulletin, Technological Quarterly, and Proceedings of the Association of Ontario Land Surveyors.

### GENERAL EXCHANGES.

Technograph of the Illinois, Year Book of Minnesota University, Scientific Magazine of Tennessee University, Proceedings of Society of Civil Engineering of Purdue University, and Annuals of Engineering Societies of the States of Iowa, Illinois, Ohio, and Michigan.

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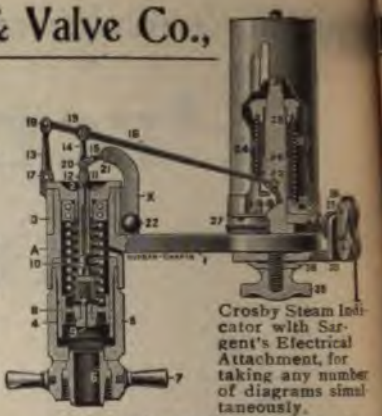

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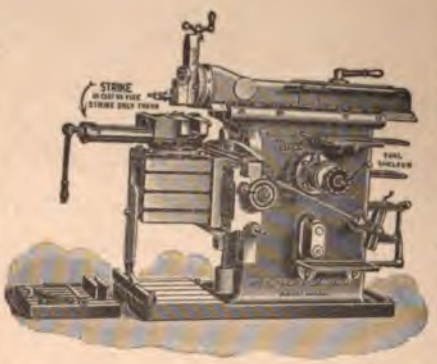

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Respectfully,
W. W. Bowley.
Chief Engr., U.S.N.

1899.

# THE TECHNIC.

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UNIVERSITY OF MICHIGAN ENGINEERING SOCIETY.

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*Managing Editor.*

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## THE STEAM MACHINERY OF THE U. S. S. YOSEMITE.

MORTIMER E. COOLEY, CHIEF ENGINEER, U. S. N.

The U.S.S. Yosemite was originally built for the Morgan Line of steamers running between New York and New Orleans. She was one of several freight steamers making regular connections with the Southern Pacific Railroad, and was in the service of the company as "El Sud" (The South) from the date of her building in 1892 until her purchase by the government in the spring of 1898. Early in April, 1898, she was sent with the U. S. S. Dixie, formerly "El Rio" (The River), to the ship yard of the Newport News Ship Building and Dry Dock Co., to be converted into an auxiliary cruiser for service in the war with Spain. The principal changes consisted in the removal of the 1-inch covering of her freight decks and the wooden stripe to keep the freight away from the bulkheads; magazines and shell-rooms were constructed in the hold; additional quarters were built for the officers and the old quarters rearranged; wash-rooms were built for the crew; sponsons were built for the battery of 6-pounders, and the decks strengthened and ports made for the 5-inch battery. The main steam piping, the steam lines for the auxiliary machinery, the fire service lines of piping and the electric wiring were placed below the water line. The upper engine room and steam steering engine, above the water line, were protected by a 2½-inch belt of nickel steel armor.

Other protection was secured by coal bunkers varying in width from four to twelve and fourteen feet. As four feet of coal affords a protection equal to one inch of armor, the principal machinery above the water line was protected by the equivalent of from three to four inches of armor when the bunkers were full of coal. Had there been sufficient time, an additional belt of armor would have been put on the outside of the ship in wake of the machinery. The main engines and boilers were examined, and such important repairs as would not delay the ship were made. The ship was docked for cleaning and painting and for examination of the propeller and outboard valves.

The new auxiliary machinery installed consisted of five double-engine ammunition hoists, three steam driven blowers for ventilating the magazines and holds, a fresh water distilling plant of 7500 gallons per day and a new dynamo.

A multitude of minor changes that could be done while the important work was in progress were also made. Additional pumps, an engine room telegraph, and a steam launch were installed.

Approximately 1000 men, working day and night and Sundays, completed this work in about two weeks time.

The Michigan Naval Brigade, who were to man the Yosemite, had been in waiting on board the receiving ship Franklin at the Norfolk Navy Yard for nearly a week. As the workmen went over the side on Saturday evening, May 7, 1898, the crew came on board, and the work of cleaning the ship and receiving stores and supplies was begun immediately. In ten days, May 17, the ship swung out into the stream, and the next morning dropped down to Hampton Roads. On the 18th she put to sea for a trial of her machinery and for target practice, returning the next day and reported ready for sea. The principal events of the cruise, chronologically arranged, have been recorded in the Michigan Alumnus, issue of December, 1898.

The hull of the U. S. S. Yosemite is of iron. She was built very substantially, and was in many respects well adapted for use as an auxiliary cruiser.

The general dimensions of this ship are given in the following table:

TABLE OF GENERAL DIMENSIONS.

| | | |
|---|---|---|
| Length over all | 405 feet, | 0 inches. |
| Breadth, moulded | 48 " | 0 " |
| Depth to awning deck beams | 33 " | 5 " |
| Displacement to 20-ft. water line | 6145 tons. | |

HEIGHT OF MASTS, BRIDGE, ETC., ABOVE WATERLINE.

| | | |
|---|---|---|
| Foremast | 128 feet, | 0 inches. |
| Mainmast | 120 " | 0 " |
| Bridge at side | 30 " | 5 " |

| | | | |
|---|---|---|---|
| Awning deck, forward | 25 | " | 11 inches. |
| " " amidships | 14 | " | 6 " |
| " " aft | 19 | " | 10 " |
| Smoke pipe | 57 | " | 0 " |
| Stay light | 80 | " | 8 " |
| Side lights | 29 | " | 6 " |
| Stern light | 23 | " | 10 " |
| Truck light | 128 | " | 0 " |
| Light on mast above hound | 88 | " | 2 " |

LOADING DATA.

| | | |
|---|---|---|
| Tons per inch at 20-ft. water line | 35 | tons |
| Moment to change trim 1 inch at 20-ft. water line | 710 | ft. tons |
| Coal bunkers, capacity of | 1290.5 | tons |
| Coal for protection | 81 | " |
| Coal in bags on berth deck | 110 | " |
| Total coal carried | 1481 | " |

FRESH WATER TANKS.

| | | |
|---|---|---|
| Ballast tank | 77000 | gallons. |
| Trimming tank | 27000 | " |
| Engine room tank | 9900 | " |
| Galley tank | 625 | " |

OIL TANKS.

| | | |
|---|---|---|
| Illuminating oil | 100 | gallons. |
| Lamp room, two tanks | 90 | " |
| Engine room, all tanks | 1,000 | " |

**Engines.**—The main engines are triple expansion, cylinders 32, 52 and [illegible] inches diameter by 54 inches stroke, not jacketed. At full speed they make from 74 to 75 revolutions per minute, driving the ship at a speed of from 14.5 to 15 knots per hour. Careful comparisons with the daily runs showed that 5 revolutions per minute was equivalent to one knot per hour, this ratio extending from about half to full speed. The main engines developed at full power about 3700 indicated horsepowers.

The engines are fitted with the Marshal valve gear as modified by Bruce Sco. The main valves are piston valves, one each for the high and intermediate cylinders and two for the low. The cut-off is controlled in all cylinders by tail screws in the radial gears. The reversing gear is the ordinary "Ram Gear" operated by steam. The condenser extends the length of the engine on one side, forming part of the engine frame work, and has 1,200 tubes, giving a total cooling surface of 5,562 square feet. The air pump is connected to the L. P. cross-head with levers, and has a water cylinder 38 inches in diameter and a stroke of 25 inches. Connected to the air pump cross-head are one bilge and two feed pumps,

of the plunger type. The cooling water is circulated through the tubes of the condenser, making three passes, by a 48-inch centrifugal pump driven by a single cylinder engine 11 inches diameter and 12 inches stroke.

**Boilers.**—There are three double ended main boilers and one single ended auxiliary boiler. Diameter of main boilers 13 feet 10 inches, length 21 feet 6 inches. Each main boiler has 6 corrugated furnaces 47 inches in diameter. The total grate surface is 493 square feet. The total heating surface is 10,316 square feet. Each boiler has two 6-inch pop safety valves set to blow off at 165 pounds pressure. The smoke pipe is 9 feet in diameter and 64 feet high above the grate. Provision is made for circulating the water in the boilers while getting up steam.

**Propeller.**—There is one screw propeller having 4 bronze blades secured to a cast iron hub. The diameter is 18 feet, pitch 22 feet.

**Indicators.**—The engines are supplied with 3 steam indicators, connections and reducing motions.

**Auxiliary Machinery.**—There was no auxiliary condenser, a serious defect in a ship having so many auxiliaries. No inconvenience was experienced with the engines in motion, but when stopped it was impossible to free the condenser of condensed steam, consequently when starting again there was a considerable loss of fresh water and the danger of wrecking the air pump. This was in part remedied by the addition of a special pump connected to the bottom of the condenser when the ship returned to the ship yard; and more recently an auxiliary condenser has been added. There are two 10x6x10-inch Worthington pumps in the engine room which can be used as feed, fire and bilge pumps, and for circulating water in the boilers, for pumping out the boilers and for operating the ash ejectors; one 8x5x12-inch Blake pump, Admiralty pattern, pumping from the bottom of the condenser and from the hot well to the boilers. There is one vertical steam ash hoist, and two Horace See ash ejectors operated by a water jet under 180 pounds pressure. Other steam pumps are as follows: One 5¼x3½x5-inch Worthington fresh water pump, one 6x8½x6-inch Blake duplex sanitary pump, and a duplicate pump for circulating water for the distillers, one 6x4½x6-inch vertical Worthington feed pump for the evaporators, and one 4½x2¾x2¾x4-inch Worthington single pump for the evaporators. There are also one No. 14½ and two No. 9½ Metropolitan injectors for feeding the boilers. The after trimming tank is fitted with a large steam siphon for filling it with sea water and for emptying it. There is also one jacking engine, five double engine ammunition hoists, three double engine winches, one steam steering engine, one steam anchor hoist, one steam capstan, and three steam driven ventilating fans. There are a total of 35 steam auxiliaries, and 53 steam cylinders.

**Distillers and Evaporators.**—The ship is provided with two evaporators having a total heating surface of 304 square feet, and two distillers having

total cooling surface of 164.5 square feet. Each evaporator contains 62 inch brass tubes, and each distiller 121 ⅝-inch brass tubes coated with tin. The maximum distilling capacity is 7,500 gallons, and the ordinary capacity 6,000 gallons of fresh water per day.

**Bunkers.**—There are 55,063 cubic feet of bunker space in which 1,290.5 tons (of 2,240 pounds) of bituminous coal, at the rate of 43 cubic feet per ton, can be, and 1,200 tons have been stowed. There are 3,119 cubic feet of bunker space around the engine room above the water line in which 84 tons of anthracite coal have been stowed. In addition to the above, 300 tons of coal can be, and 134 tons have been stowed in bags on the berth decks.

**Electric Lights.**—The engine room and shaft alley are lighted by 27 16-candle incandescent lamps of 16 candle power each, and the fire rooms by 16 lamps. There are, besides, 9 lamps for general use in the engine department. There is one General Electric Co., direct connected engine and dynamo. The diameter of cylinder 6½ inches, stroke 5 inches, 450 revolutions per minute. Dynamo, 91 amperes, 110 volts. There was, also, one E. W. Payne Co. engine, diameter of cylinder 7 inches, stroke 8 inches, 250 revolutions per minute, connected by belt friction pulleys to a Eureka dynamo (Loomis System), voltage 100, amperes unknown. This has since been replaced by a second generating set like the first.

**Steam Launch.**—Length of hull 30 feet, breadth of hull 8 feet, depth of hull 3 feet, draft of water forward 2 feet, aft 3 feet. Diameter of H. P. cylinder 3½ inches, L. P. cylinder 7 inches, stroke 7 inches, keel condenser. It is fitted with a Ward boiler, having seven square feet of grate surface. The bunker capacity is 500 pounds of coal, and the fresh water tank capacity 50 gallons. Speed of launch 8 knots.

**Synopsis of the Log.**—Between May 16 and September 22 the total time that the engines were in operation was 1432 hours; after getting fairly under way, 1328 hours. The total number of revolutions made was 3,542,610; after getting fairly under way, 3,455,610. The total number of knots made was 11,808. The total weight of coal used for all purposes was 2,911 tons (of 2240 pounds); and for steaming purposes, 2,560 tons. The total weight of refuse from coal, for all purposes was 341 tons, and for steaming purposes 247 tons. During this entire time there were no breakages or casualties of importance.

On June 30 a somewhat extensive fire was discovered in the starboard bunker overhanging the boiler room. It was found to be located at the bottom of the bunker under about 8 feet of fine coal, and had evidently started in the wooden floor which was in a semi-charred condition due to nearly 6 years service. The arrangements were such that the fire could not be extinguished with steam, and the gas arose in such quantities as to prevent workmen from handling the coal. The fire could not be reached by water owing to the fine condition of the coal. In this emer-

gency a hose was lashed along a slice bar (about 9 feet long) with the nozzle about 6 inches from the end. With two men to handle the hose and bar and with a pressure of from 80 to 100 pounds per square inch, the bar could be pushed through the mass of coal in any direction and to the bottom of the bunker delivering the water immediately into the fire. These fires were of almost daily occurrence for the following two weeks but caused no further anxiety.

The steam machinery responded promptly to all demands made upon it. At the close of the year this ship was selected and fitted out for prolonged service as the station ship at Guam in the Ladrone Islands.

**Engineer Force.** — The complement allowed the engine department during the war was as follows: 1 chief engineer, 1 assistant engineer, 1 engineer's yeoman, 4 chief machinists, 3 machinists of the first class, 3 machinists of the second class, 1 boiler maker, 1 blacksmith, 1 coppersmith, 3 water tenders, 3 oilers, 16 firemen of the first class, 16 firemen of the second class and 18 coal passers, a total of 72 officers and men.

**Maximum Engine Performance.**—Date, September 21, 1898.

| | |
|---|---|
| *Number of hours, 5 P. M. to 7 P. M. | 2 |
| Speed in knots per hour | 14.8 |
| Moderate wind and sea on the starboard bow. | |
| Revolutions per minute | 74 |
| **Steam Pressures,** in pounds, per square inch, gauge. | |
| In boilers | 160 |
| At engine | 155 |
| First receiver | 59 |
| Second receiver | 16 |
| Vacuum in condenser, inches | 22 |
| Point of cut-off, in all cylinders | 0.76 |
| Throttle, wide open. | |
| **Temperatures,** in degrees Farenheit. | |
| Engine room | 80 |
| Fire room | 90 |
| Injection water | 71 |
| Discharge water | 110 |
| Feed water, no thermometer | |
| Draught of vessel, not logged. | |
| Circulating pump, revolutions per minute | 125 |
| **Indicated Horse Powers.** | |
| High pressure cylinder | 1256.5 |
| Intermediate pressure cylinder | 1333.5 |
| Low pressure cylinder | 1120.9 |
| Aggregate | 3710.9 |
| Auxiliaries in use, estimated | 39.1 |
| Collective | 3750 |

*The performance from 2 P. M. to 8 P. M., 6 hours, was practically the same.

**Economic Results.**

| | |
|---|---|
| *Coal burned per hour, pounds | 8492 |
| Coal per indicated horse power, per hour | 2.26 |
| Grate surface in use, square feet | 492.40 |
| Coal per square foot of grate surface, per hour | 17.21 |
| I. H. P. per square foot of grate surface | 7.69 |
| Heating surface in use, square feet | 10516.10 |
| I. H. P. per square foot of heating surface | 0.36 |

**Coal Consumption at Different Speeds.**—No runs were made for the purpose of determining accurately the coal consumption at different speeds. The log furnishes data, however, from which this important information may be had approximately. This is presented in the following table:

†TABLE OF COAL CONSUMPTION AND STEAMING RADIUS AT DIFFERENT SPEEDS.

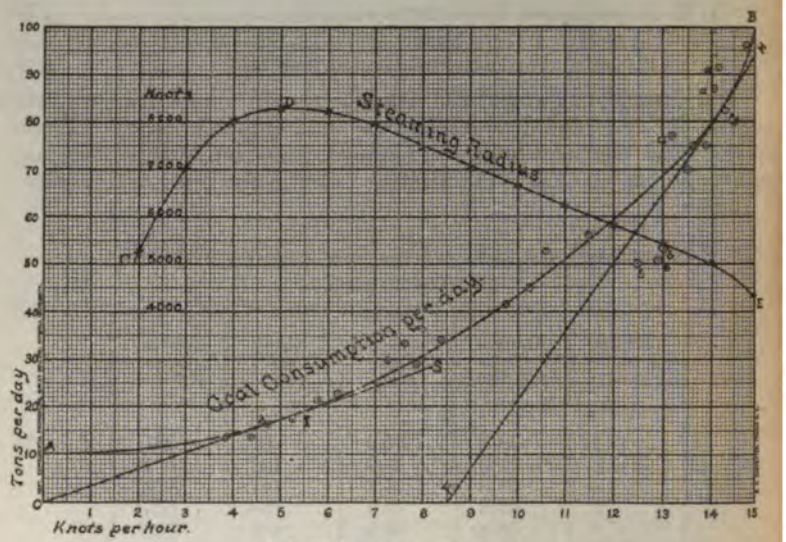
| Knots per hour. | Tons of coal per day. | No. days steaming. | Knots per day. | Steaming radius. |
|---|---|---|---|---|
| 4 | 14.4 | 83.3 | 96 | 7997 |
| 5 | 17.4 | 68.9 | 120 | 8268 |
| 6 | 21.0 | 57.1 | 144 | 8222 |
| 7 | 25.5 | 47.1 | 168 | 7913 |
| 8 | 30.8 | 38.9 | 192 | 7469 |
| 9 | 36.8 | 32.6 | 216 | 7042 |
| 10 | 43.4 | 27.7 | 240 | 6648 |
| 11 | 51.0 | 23.5 | 264 | 6204 |
| 12 | 59.4 | 20.2 | 288 | 5818 |
| 13 | 69.0 | 17.4 | 312 | 5429 |
| 14 | 80.0 | 15.0 | 336 | 5040 |
| 15 | 100.0 | 12.0 | 360 | 4320 |

The second column shows the daily coal consumption for the speeds given in the first column. The quantities were taken from a curve plotted from thirty points furnished by the log, and varying from a speed of 3.6 knots to 14.8 knots per hour. The coal consumption with the main engines at rest and with all auxiliaries in use was found to average 10.1 tons per day. Of this amount 5 tons were used for distilling water for the ship's use. The quantity distilled averaged about 6000 gallons per day. That not required for immediate use was stowed in reserve tanks. The boilers were in use much of the time.

*Pocahontas and New River mixed.

†Based on the bunker capacity of 1200 tons of coal.

In the accompanying plate AB is the coal consumption curve, starting at 0-speed with 10 tons, and reaching at a 15-knot speed 100 tons. The group of points, *a a a*, are from an inferior grade of coal. The group, *b b b*, are evidently errors of entry in the log.




U. S. S. YOSEMITE (EL SUD).
Curves of Coal Consumption per day and Steaming Radius.

**Economical Speed.**—The tangent OS gives the economical speed at the point of tangency I; for at this point the ratio of coal consumption to speed is a minimum. Therefore, for this ship the most economical speed is about 5.5 knots. It must not be inferred, however, that such a speed would be a proper one at which to drive the ship in regular service. The coal consumption is only one of the items entering into the cost of operating a ship. For example, the interest on the cost of the vessel, taxes, insurance, depreciation and repairs, pay and messing of officers and men, oil, waste and other supplies must all be considered. In the merchant service, these items would aggregate not far from $250 per day; reduced to a coal basis, coal at $2.00 per ton, this would mean 125 tons. With this quantity a new tangent F H may be drawn, starting from a point on the vertical axis below O, and touching the curve at G. This would give an economical speed of about 14.3 knots per hour, which is the speed at which the ship was operated in the merchant service.

**Steaming Radius.**—From the coal consumption per day at different speeds, we may find the number of days the ship may remain at sea,

shown in column 3 of the table; and the distances she may steam with a given quantity of coal, column 5. The quantities in column 5 may be plotted, giving the curve C D E. The ship can steam 8208 knots at 5 knots per hour, 6648 knots at 10 knots per hour, and 4320 knots at 15 knots per hour. With 1500 tons of coal, instead of 1200, these quantities are increased 25%, making the maximum steaming radius 6225 knots.

## TOWN, CITY AND VILLAGE PLATS IN MICHIGAN.

J. R. DAVIS, '68.

1. **How Platted.**—A village, or city; an addition to a village or city; or a sub-division of a parcel of land; is platted by first being surveyed, and then divided into lots, mapped, recorded, and a copy of the record filed with the Auditor General at Lansing, all according to the provisions of the statutes relating to plats and taxes, and the terms of the village or city charter.

2. **When Platted.**—Such a plat must be made whenever the plan of such lands is laid out, altered, or vacated. The work may be done by any competent person.

3. **Platted by Supervisor or Assessor.**—If the proprietor lays out land into lots, or sells by metes and bounds, and fails or neglects to have made and recorded the plat of the same, as required by law, the supervisor or assessor, when authorized by the township board, or common council, or trustees, of the city, or village in which such land lies shall cause a plat to be made under his hand and seal, and recorded and filed as above noted. Such supervisor's or assessor's plat shall be treated as if made by the proprietor, in respect to assessment, collection, and return of taxes, but shall not interfere with vested rights. The town, city or village in which the land lies shall pay for such supervisor's or assessor's plat.

4. **Survey First.**—The survey on the ground must precede the mapping and record.

5. **Surveys.**—The first work is to ascertain the actual boundaries of the piece of land to be platted, and to mark those boundaries by permanent monuments planted in the ground at all angles in them. Witnesses must be recorded for all these monuments, and descriptions of the materials used, and the character of their construction preserved, to be entered on the sheet of paper containing the plat. The lengths of all the lines of these boundaries, and their angles of intersection must be ascertained and recorded, to be used in making the plat. These boundaries must be connected with the lines of adjoining, or related surveys, preferably with those of the U. S. Land Survey, and records of such connections preserved for use on the plat. It is best also to compute, by latitudes and

departures (or traverses), checks for the survey enclosing the land to be platted, and prove the same to be correct before proceeding further with the work. If there are streets, highways, railroads, canals, or any lines of travel, or existing works, crossing, joining, bounding, or running to, or abutting on, the land to be platted, the lines of all such must be connected with the boundaries surveyed, and a record of such connections kept for use on the plat, and for a guide in planning the streets and lots. It is best to mark such lines and connections with permanent monuments, as the boundaries are marked, taking and recording similar data for finding them again. Similar data must be obtained for all ditches, water courses, shore lines, and plain natural lines of demarkation, such as the edge of a marsh, or the top or bottom edge of a steep slope or cliff, for use on the plat; for preserving a record of these things, and for use in making the street and lot plans. Pieces of land not to be platted, but which are embraced, wholly, or partly, by the plat, must be surveyed, monumented, and recorded, as completely as the land to be platted, so far as included within the plat.

6. **Field Map.**—When the surveys have been carried far enough to profitably begin mapping, make a large scale map showing the above described information. Lay out on this map the street plan, and all lines of travel, with public grounds and special sites, if there are to be any. Fit the streets to connect with existing streets, or works. Fit them to the ground as well, to give good grades, desirable lots, and proper drainage. By this time it will be plain whe her the surveys previously made have furnished all needed information or not. If not, they should be completed and the map perfected in accordance therewith. So complete the plans for the streets, lines of travel, public grounds, and special sites, if any. Fill in the lots. Get approximate dimensions, erring by being too small. Submit the map to the proprietor. Alter it till approved by the proprietor. Name all streets and enter their names on the map. Number all the lots continuously over the whole map, so there will be but one lot on the map bearing any one number. Use this map to lay out the streets, alleys and lots by. Record thereon every angle and dimension measured during subsequent surveys. Mark thereon every monument planted and every lot stake driven. Fasten the map securely on a drawing board and take it in the field when laying out the streets and lots. If it is too large for this, have the contents of the note books copied on to it daily, or cut it up in pieces and use them in the field—also a tracing may be made for field use. This map should be kept in the field, while completing the surveys.

7. **Marking Plat on the Ground.**—Survey out all streets, alleys, public grounds, and special sites, in the order named. Plant a monument in the ground at the intersection of all streets with other streets, alleys, and the boundaries of the plat. Similarly for alleys. Mark all angles of streets,

e alleys, or points of special importance, such as the tangent points of curves, in the same manner. Add monuments sufficient to preserve every controlling line of the work, as at the intersection of the tangents to a curve. Record witnesses for all these monuments, to go on the paper with the plat. Make a note on the survey map of all angles, lengths of all lines, and location of all monuments, as soon as obtained. Survey out the lots. Drive a lot stake at every angle in every boundary of every lot and measure the length of every side of every lot. Mark every lot stake on the survey map as soon as driven and record on it every dimension as soon as measured. Check all measurements of angles or distances by a sufficient number of comparisons to verify every detail of the work.

8. **Must Not Sell Lots.**—The proprietor must not sell lots till the statute is fully complied with. The penalty is ten dollars for each lot so sold.

9. **Three Plats.**—Three plats must be made by a competent person. One is for the proprietor, is called the "Original," and bears on its face the evidence that the statute has been complied with. This plat is to be used, in a sense, somewhat as one would exhibit a deed to show title, as it does show that the purchaser of a lot would not have a cloud on the title to it because the statutes governing plats had not been complied with. The second plat is for the office of the Register of Deeds for the county in which the land lies. It is called the "Record," as it is to become the record of the plat. The third plat is for the office of the Auditor General at Lansing, and is called the "Copy of the Record," for such it will become.

10. **Original Plat.**—The "Original" plat must be made first; sent to the Auditor General, his approval obtained, and endorsed on its face, and returned to the person making the same, before the other two plats are made. The Auditor General may return the plat for correction till in his opinion it conforms to the requirements of the statutes.

11. **Paper Used, What Goes On It.**—The paper for the three plats must be good cloth backed drawing paper. The sheets must be 18 by 24 inches, the long side usually being taken for the bottom of the sheet. A margin of one inch outside the border is sufficient. All matters and things relating to the plat, including the description, dedication, acknowledgment, notary's seal, and all certificates, must go on the paper with the plat, on the same side of the sheet and within the border line. If one sheet will not contain all the matter required by law, a sufficient number of sheets may be used. Each sheet should then state the whole number of sheets, and its own number in the series, as:

Whole number of sheets.....7 Number of this sheet.....3

The acknowledgment, certificates, and the like, need not be repeated on the different sheets, but the whole series be treated as if but a single sheet.

12. **Original Must Contain.**—The "Original" Plat must contain:

Plat.
Title.
Scale.
Meridian Mark.
Explanations, if needed.
Description.
Monuments.
Surveyor's Certificate.
Certificate of Approval by Council, or Board.
Tax Certificate.
Dedication.
Acknowledgement.
Notary's Seal.
Certificate of Approval by Auditor General.
Certificate of Record.
Receipt of Auditor General for "Copy of Record."

13. **Record Must Contain.**—The "Record" must contain the same as the "Original," except the last item, and certificate of comparison with the "Original."

14. **Copy of Record Must Contain.**—The "Copy of the Record" must contain the same as the "Record" and Certificate of Comparison with the "Record."

15. **Fees.**—Register of Deeds, two dollars; Auditor General, one dollar.

16. **Penalties.**—Proprietor, ten dollars, for each lot sold before complying with the statute.

Register of Deeds, ten dollars, for willfully recording a map or plat not conforming to all the legal requirements, and in addition be held liable to pay all damages which any person may sustain by reason thereof.

Register of Deeds, one hundred dollars, for receiving and recording a plat without the proper tax certificate being presented with it, and further be liable to the grantee of any instrument so recorded for the amount of damages sustained.

17. **Plat.**—The plat must be a correct representation of the preceding survey on the ground, on a scale showing not over 200 feet to the inch. It must give the form and dimensions of every piece of land, or lot, within it, and all angles. It must show the portion of the U. S. Land Survey included in the ground platted, or represent that ground by correct metes and bounds, connected with the lines of adjoining, or related, surveys, preferably with those of the U. S. Land Survey. When a subdivision is made of any part of a previous plat, the lot or lots, block or blocks, or parts of said plat must be distinctly shown, and its connection and relation, with the rest of the plat, accurately designated. The ground platted must be shown by lines and appropriate letters and figures, so that the length and direction of every side of every piece is plain from the plat, without reference to the written description. Mark the starting point of the written description on the plat with the words, "Place of Beginning."

All public grounds and special sites, except streets and alleys, must

be plainly represented, and show the exact extent of the same by exhibiting the lengths and directions of all their boundaries.

All streets and alleys are to be shown by their courses, lengths, widths and names, or numbers, by writing, lettering, and figures on the plat.

Show the exact location of every monument by a small plain circle for each one, with its center at the point marked on the ground by the monument.

All lots must be shown and numbered as directed in 6. The plat must give every dimension of every boundary of every lot. If there are many lots having the same dimensions, the same dimensions need not be unnecessarily repeated, but be indicated by two marks each, if this can be done without leaving any uncertainty as to any dimension of any lot. Especial pains must be taken to show clearly every dimension, the true form, and the certain location and extent of all lots of an unusual or irregular shape, such as those lying between streets not parallel, or meeting at an oblique angle; or lots purposely made irregular to avoid bad angles for buildings between such streets; or lots bounded by curves, or bordering on a railroad curve; or those lying along bodies of water, such as ponds, lakes and streams, or in similar situations. If a lot has a curved boundary, the radius of the curve and the location of its center must be shown as well as the actual length of the curved boundary measured in a designated number of chords. It is well also to give the central angle of such curve as it is not apparent from the other lines and angles on the plat.

Every angle must be shown on the plat, or the course of every line on it. This includes the angles at all the boundaries of the land platted, and their connections with adjoining surveys, whether of lands, streets, highways, railroads, canals, or what not. In the case of streets and alleys all angles must appear at every intersection with other streets or alleys, and where any or either of them intersect the boundaries of the plat or the adjoining surveys. If curves are used the central angle for each one must be recorded on the plat, with the correct location of its center, its radius, its length, measured in a given number of chords, which must be stated, and the positions of its tangents plainly represented, with their length. In all lots, whether regular or otherwise, unless the angles of their boundaries can be readily discerned from the data on the neighboring lines, said angles must be recorded on said lots in their proper places. If deflection angles are used in the "Description" of the land platted, these should be shown on the plat by prolonging the boundary lines with a broken or dotted line, and writing them in where they belong, so they will appear in due order and direction, as one reads the description and compares it with the plat.

Pieces of land not platted, but embraced, wholly, or partly, in the survey for the plat, must be distinctly shown on the plat with the same data for exact location, extent, form, dimensions, and connection with

adjacent lands, that is recorded for the land that is platted. These pieces should be surrounded by a somewhat broader line than is generally used elsewhere on the plat, and they must be plainly lettered: "Not Included in this Plat."

The drawing should be done in black. Colored lines fade. The lines should be plain and strong. The monument lines of the streets and alleys should be drawn finer, and dotted, or broken, but plain. The street widths should be noted in plain figures, showing the distance from the monument line, each way to the property lines. Shade lines may be used with good effect by inking the north and the east property lines on blocks with distinctly broader line.. Any representations of buildings, railroads, bridges, or structures of any kind, though very seldom necessary, or topographical signs, should be neatly and plainly done. Line shading, occasionally useful, should be made sufficiently open to permit of its being uniformly well done with fine (not ragged) lines.

All lettering on the plat itself should be plain and simple as it can be made, and no more prominent than the plat itself, to which it is subordinate. This refers to the lettering in streets, alleys, public grounds, special sites, excepted lands, and the like. The plat is made for the purpose of conveying legal information regarding the survey made on the ground, and everything on it should be an aid in doing this. Lettering, nor anything else can take the place of a plat, and ought not to be allowed to obscure the plat. Put on the lettering last, but have a regard for it while planning the rest of the work.

Lot stakes may be indicated on the plat by small round dots, made with a close set bow pen.

18. **Title.**—The Title to be used varies somewhat with circumstances, but must always contain the name of the township, city, or village, and State, in which the land platted lies; the name of the plat; and any other words, or numbers, required to distinctly distinguish it from any, and every other plat in the State. If the plat is a first one, made to locate and subdivide into lots, the land for any city or village, the title should include the full name of such city, or village, the county in which it is situated, and the name of the State. If the plat is an addition, extending the platted area of any city, or village, the title should include the name of such addition, with that of the city, or village, and the State. If the plat is a subdivision of lands already platted, the title should give the name of the subdivision, the designation of the lots, or lands, subdivided, the name of the previous plat, or plats, the name of the city, or village, and the State. If a plat is the replat of certain lots, or lands, of a former plat, call it a subdivision, and give it a corresponding title. If a plat covers ground not part of any former plat, while yet well within the city, or village, boundaries; or land entirely without those boundaries; or any land to which a distinctive name may appropriately be

attached, it is better to give it such a name in the title, and add, as a sub-title the name of the city, or village, and State. These typical cases may be sufficient to suggest the proper form of title, and the words to be used, in any case.

The lettering used should be fully subordinated to the purposes of the plat, and not overshadow the rest of the work on the sheet, or sheets. If more than one sheet is used, the title must be repeated on every sheet.

19. **Scale.**—A scale must be drawn on the sheet with the plat, correctly representing the linear measurements on the plat. A plain, neat form of scale diagram should be used, to which should be added a statement of the scale in feet to the inch.

20. **Meridian Mark.**—There must be drawn on the sheet with the plat, a meridian mark showing plainly, by the use of letters, in a general way, all of the four cardinal points of the compass. The design should be simple and useful, not too large, and never obtrusive in its prominence.

21. **Explanations.**—Explanations of certain matters not otherwise perfectly plain on the plat, may be needed. These should always state the unit of linear measurement, as "Dimensions in feet" or "Dimensions in chains." But one unit of measurement should be used. Representations of certain things should be exhibited with explanations, such as monuments, lot stakes, or any special signs used. There should be a sketch made showing the general method of placing and constructing monuments, and the manner of using the materials of which they are made. No doubt of the signification of anything whatever on the plat should be permitted to remain unexplained. Many things quite plain to a surveyor, or draftsman, are not understood by people in general, or may be made the subject of question by design.

22. **Description.**—A description of the land platted must be written on the sheet containing the plat. If more than one sheet is used the description need not be written but once. It must be full and detailed; give the township, range, and section of the U. S. Land Survey, in which the land is situated; and the name of the town, city, village, or addition, platted. It should be complete in itself, needing no reference to the plat for a competent person to locate the land on the ground. Verbosity and repetitions are to be carefully avoided. The land should be described but once. That is, no unnecessary words should be used, and but one interpretation to those that are used should be practicable. If subdivisions of a section, by the U. S. Land Laws, are embraced in the plat the regular description commonly applied to such must be used. If metes and bounds are used, the connection with monuments and lines of the U. S. Land Survey should be given whenever practicable, otherwise, connections and references to adjoining surveys, former surveys, and records, sufficient to unmistakably designate the land. To connect the descrip-

tion with the plat, reference to it should be made by capital letters referring to the same letters on the plat, as "A to B," "C to D." Lands not included in the plat but lying within the boundaries thereof should be noted in the description, as excepted. If the description includes any part of a highway or other line of travel, or any lands subject to any kind of an easement, the facts, as far as can be, should be stated in the description. Stump writing is suitable for entering the description on the paper. The matter should be neatly arranged. When practicable, the data for each side should occupy a separate entry, the entries being numbered in order. The description should begin, as follows:

DESCRIPTION OF LAND PLATTED.

The land embraced in the annexed plat of----------
----------is described as follows:
---
---

23. **Monuments.**—Monuments must not only be represented on the plat, as noted in 17, and explained and illustrated, as noted in 21, but the witnesses for them, taken during the survey, when permanent objects were found in their vicinity, must be recorded on the paper with the plat, together with any other information that will assist in finding, or restoring them. A systematic form of record should be used.

24. **Surveyor's Certificate.**—The surveyor, or engineer, or competent person acting as such, must certify that the plat is a correct one, and that the monuments described in it have been planted as therein described. The following is the customary form:

SURVEYOR'S CERTIFICATE.

I hereby certify that the plat herein delineated is a correct one and that permanent monuments consisting of----------
----------have been planted at points marked thus------as thereon shown at all angles in the boundaries of the land platted, and at all the intersections of streets, or streets and alleys.

----------
Surveyor.

25. **Council or Board Certificate.**—In order to comply with the general law incorporating cities and villages; the provisions of the charter of any city or village; or the requirements of any township board, village trustees, city council, or other body having the rightful oversight of the plat, it may be necessary to include a certificate of approval by such body. This certificate might be of the form below:

CERTIFICATE OF APPROVAL.

By ----------
---
This plat was examined and approved at a----------

meeting of the.....

.....

.....

this.....day of.....19.....

.....

Clerk.

68. **Tax Certificate.**—The Register of Deeds shall require from the person presenting the plat for record a certificate from the Auditor General or from the county treasurer of the county, whether there are any tax liens or titles held by the State, or by any individual, against any of the land embraced in the plat, and that all taxes due thereon have been paid for the five years preceding to the date of such plat, and in default of the presentation of such certificate he shall not record the plat until such certificate is secured and presented. The Register of Deeds shall note the fact on the plat that said certificate has, or has not, been presented to him when the plat is presented for record, and in case the person presenting such plat shall refuse to procure such certificate, he shall endorse that fact upon said plat over his official signature, and shall refuse to receive and record the same.

The statement of taxes furnished by county treasurers is considered sufficient to comply with the law, but few calls being made on the Auditor General for the purpose. It is suggested that the form used by the county treasurer be copied directly on to the plats. One of these forms is as follows:

TAX CERTIFICATE.

County Treasurer's Office,
.....County, Mich.,
.....Mich.,.....19....

It is hereby certified that the following statement shows the condition of Lands described below in the County of.....so far as relates to the State and County taxes prior to the.....day of .....19....., to-wit:.....

.....

[Description of Lands.]

.....

.....

as appears by the records of this office.....

.....

[State Delinquent Taxes, if any, during five years prior to date of plat.]

.....

.....

.....

County Treasurer.

Obtain the treasurer's certificate and copy it on to the plat to save space that might be wasted if an attempt was made to allow for items

2

not yet known. Below the tax certificate, add for signature by register the following words:

Above Tax Certificate was presented with this plat.

---

Register of Deeds for said County.

In certain cases no tax certificate is required.

1. Plat for incorporation of a city or village, if it is part or all of a plat already on record, or in so far as the description is not changed.

2. Copy of a lost or destroyed plat.

3. Sheriff's or Commissioner's deeds given under law or decree of a court of this State.

4. Deed of Trust by an assignee, executor, or corporation, given pursuant to State law.

5. Deeds without a warranty.

6. Land Patents, U. S. or State.

7. Tax Deeds of Auditor General.

8. Deed of a railroad company conveying its right of way, if accompanied by certificate of Auditor General that all specific taxes due from said railroad company are paid, including the year the deed is executed.

For the penalty see 16.

**27. Dedication.**—The dedication should be in the following form, somewhat varied in particular statements to suit particular circumstances. It must contain the name, or names, of the proprietor, or proprietors, and their wives, and must be signed by all those whose names are mentioned, and these signatures verified by two witnesses the same as for deeds. In case the proprietor is a bachelor or widower, this fact should be stated to account for the absence of the signature of the wife. If there are several proprietors, with, or without wives, the names of all may be included in the one dedication, in an orderly manner, mentioning the wives, if any, even though their signatures must be obtained in different places, or in other states. If the signatures of all parties can be obtained at the same time and place, spaces for two witnesses will be enough, otherwise there should be two spaces for signatures of witnesses for each signing, accompanied by a statement of whose signatures each pair of witnesses are to verify. Every man and his wife who may be in any manner concerned in contributing land for the purposes of the plat should sign the dedication. This is sometimes overlooked in the matter of opening streets or parts of streets, or in relation to some small strip or parcel of land taken for the plat. Particular attention should be given to obtaining the signatures of all parties concerned, in exactly the same manner as if making a deed for the land embraced in the plat.

DEDICATION.

Know all men by these presents, that we----

----as proprietor, and----

.....his wife, have caused the land embraced in the annexed plat to be surveyed, laid out and platted, to be known as.....

[Insert title of Plat.]

.....

and that the streets and alleys as shown on said plat are hereby dedicated to the use of the public.

Signed and sealed in the presence of .....[L.S.]

.....[L.S.]

.....

28. **Acknowledgment.**—Plats must be acknowledged as deeds are acknowledged. This calls for a form of acknowledgment similar to that used in deeds to follow the *Dedication* on the plat. The following is the usual form.

ACKNOWLEDGEMENT.

State of Michigan,}
County of.....} ss:

On this.....day of.....190..... before me, a Notary Public in and for said county, personally came the above named.....and.....his wife, known to me to be the persons who executed the above dedication and acknowledged the same to be their free act and deed.

.....

Notary Public.....Co., Mich.

The above wording may be changed to designate any other proper person before whom deeds, and consequently plats, may be acknowledged. The above wording may be changed to designate the proprietors whoever they are. They may all be named and their acknowledgements all taken at one time and before the same official. If the plat has to be sent to different places to get the signatures of the different proprietors there must be as many forms of acknowledgement provided on the plat as there are to be persons before whom the acknowledgements are to be made, each one containing the designation of the proper official before whom it is to be made and the names of those who are to make it. If the plat is to be sent out of this state for signatures and acknowledgements, it is better to name some official of the state to which it is to be sent, whose position and seal is legally known in Michigan, as this will save attaching to the plats sealed certificates from proper authorities to establish the official position of the person taking the acknowledgement,—as would be the case for a Notary Public. The surveyor should take the advice of the Auditor General, or of an attorney in this matter.

29. **Seals.**—Places for the seals should be left just within the border line, so they can be reached with the stamp. Strike a two inch circle with a pencil and write, in pencil, within it the words "Seal here." These pencil marks can be erased when the plat is returned. There must be a

place to seal every form of acknowledgement, adjacent to it. This will require some planning when getting ready for the plat, in order to bring them all next to the border line.

30. **Auditor General's Certificate.**—The certificate of approval by the Auditor General will be furnished by him, but a small space for it should be left, about one by two inches. The proper place for this space is following the *Acknowledgement* and *Seal*.

31. **Certificate of Record.**—The certificate of record should be of the ordinary form found on the back of deeds, such as the following:

CERTIFICATE OF RECORD.

Register's Office, }
----------County } ss:

Received for Record the----------day of----------19----
at--------o'clock----M., and Recorded in Liber-----of Plats, on Page-----

----------
Register.

32. **Record.**—After the original plat is returned from the Auditor General bearing the certificate of his approval the other two copies are to be prepared. They may be made by any competent person. The first is the record and must contain everything entered at this time on the original, and in addition the certificate of comparison with the original, in the following form:

CERTIFICATE OF COMPARISON WITH THE ORIGINAL.

State of Michigan, }
County of--------} ss:

We----------Register of Deeds in and for said county, and----------of----------Surveyor, hereby certify that we have each carefully compared this copy with the original plat of----------[Title of Plat]---------- and that it is an exact copy thereof and of the whole of such original map or plat.

----------Register of Deeds.
----------Surveyor.

This certificate may be signed at different times, and places, by the Register of Deeds and Surveyor, and comparisons may be separately made. The most convenient method of comparison is to take the three finished plats to the Register of Deeds, give one to each of three qualified persons, let the original be read aloud, and the other two compared with it at once.

33. **Copy of Record.**—The copy of the record should be next prepared. This must contain everything entered on the first copy, and in addition the following certificate of comparison with the record.

CERTIFICATE OF COMPARISON WITH THE RECORD.

State of Michigan, } ss:
County of ..... }

We.....Register of Deeds in and for ..... county, and.....of.....Surveyor, ..... hereby certify that we have each carefully compared the annexed copy of the plat of.....[Title of Plat].....now ..... recorded in the office of said Register of Deeds, and that it is a true transcript therefrom and of the whole of each record.

.....Register of Deeds.
.....Surveyor.

This comparison may be made separately by the two parties, and the certificate separately signed as in the case of the last

Corrections.—Often overlooked or omitted.

From the original Plat:

- Angles.
- Place of beginning.
- Data to correspond with description.
- Proper marking of excepted land.
- Widths of streets, or alleys, each side of monument lines.
- Names of—
  - Streets.
  - Parks.
  - Grounds.
  - Natural objects:
    - Ponds.
    - Lakes.
    - Streams.
  - Adjoining plats.
  - Adjoining land owners.
  - Original highways.
  - Railroads.
- Proper designations of old land marks.
- Scale.
- Meridian mark.
- Marks for monuments.
- Sketch of Monuments.
- Part of a Full Title.
- Explanations.
- Items skipped in copying the description.
- Records of witnesses to monuments.
- Certificate of Approval by Council, or Board.
- Tax Certificate.

Names of some of those who are proprietors, in some particular, or the names of their wives, from the Dedication.
Errors, or omissions, in Acknowledgment similar to Dedication.
Acknowledgment does not correspond to Dedication.
Seal spaces.
Certificate of Record.
From the Record:
Certificate of Record.
Auditor General's Certificate of Approval.
From the copy of the Record.
Certificate of Record.
Auditor General's Certificate of Approval.
Certificate of comparison of the record with the original.

**35. Inspections and Duties.**—Look over all the sheets carefully in every detail and take particular pains to make sure there are no errors, or omissions, and that the plats are true duplicates. Take, or send them, with the tax certificate to the Register of Deeds of the county in which the land platted lies, and complete the comparisons and signatures called for by 32 and 33. The Original and Copy of the Record with the tax certificate should be returned to the person who made them, that is, to the surveyor. He should examine the sheets and see that the part of the Register of Deeds has been properly performed. The tax certificate should be preserved with the Original Plat. Wrap the Copy of the Record and mail it, with a letter, stating the address of sender, and enclosing the fee of one dollar, to the Auditor General at Lansing, Michigan. When his receipt for the Copy of the Record, and fee, is received, attach it to the Original Plat. Return the Original Plat, with receipt attached, and tax certificate to the owner of the property. The sales of lots may then properly begin.

**36. Legal Questions.**—The outline here presented covers the simpler operations. Legal questions continually arise which are beyond the province of the surveyor. These questions, when comprehended as fully as practicable, should be submitted to the Auditor General for his direction. What form of dedication and acknowledgement should be used when the proprietor is a corporation; or an estate; or a number of heirs; or in case the land is to be platted by supervisors or an assessor? Such inquiries should be submitted to the Auditor General. In many other matters the Auditor General is the best guide the surveyor can have, as he is the official designated by law to see the provisions relating to plats carried out. Such consultations lead to more uniformity in practice in various parts of the State. It is the surveyor's plain duty to faithfully endeavor to carry out, or comply with, the instructions of the Auditor General.

**37. Detached Parcels.**—Detached parcels of land cannot be included

in one plat, but separate plats must be prepared for each. Two plats cannot be shown on the same sheet. Separate sheets must be used for the separate plats. Adjoining lands owned by different persons may be included in one plat, all the owners, and their wives, joining in the dedication and acknowledgment. It is not necessary to designate the parts owned by each person.

38. **Date.**—The date of a plat is the date of the Auditor General's receipt for the Copy of the Record and the fee, as on this date compliance with the plat law was completed.

39. **Signature.**—A signature must be made by the person whose signature it purports to be in the same manner as is required in deeds. In case the signer cannot write there must be the proper "Mark" witnessing with space left for same on sheet. A rubber stamp is not a signature, neither can any other device be used. With a pen and ink is the only proper signature made, as if making a deed of the land, and by the proprietor or wife in person.

40. **Duties of Register.**—The copy of the Plat which becomes the Record is to be fastened securely by the Register of Deeds in a strongly bound book, furnished by the county to receive 18-inch by 24-inch sheets without folding. The surveyor should observe that this is done. This copy then becomes a record the same as if transcribed by the Register. The Register must fill out the certificate of record on the original, as to liber, book, and page, the same as for a deed. He must note the time on the record, but to make all three plats alike, the certificate of record had better be used throughout. This will also make the copy of the record show where it is recorded as well as when. The Register must keep an alphabetical index to plats. After a proper delay, it is well for the surveyor to see that the plat is properly indexed, if convenient for him to do so. The Register's fee is two dollars, is to be paid by the proprietor, and is in full for all services rendered.

41. **Duties of Auditor General.**—The copy of the record must be delivered to the Auditor General at Lansing, after being compared with the record and certified by the register and surveyor. He shall file this copy in his office, and shall keep an alphabetical index of plats, with any other aids for reference. His fee is one dollar, to be paid by the person delivering the copy.

42. **Prima Facie Evidence.**—The Original Plat with the certificate of record on it, or the Record, made as per 40, or a certified transcript of the Record shall be, in courts of this State, *prima facie* evidence of making and recording such plat in conformity to the statute. The Copy of the Record in the Auditor General's office, or a certified transcript thereof shall be, in courts of this State, *prima facie* evidence of the above matters and also the filing of said copy in the Auditor General's office.

43. **Fee of Public Grounds.**—A plat legally made and recorded shall be

deemed a sufficient conveyance to vest the fee of the lands designated for public use in the township, village, or city, in which they lie, in trust for the purposes designated, and for no other purpose.

44. **Notice.**—In making the surveys, collecting data, and making the plat, the surveyor should notice that Section 1474 of the plat law is to be considered in connection with the fifth clause of Section 1473.

45. **Plat Law.**—The following is the copy of the statutes relating to the making, and recording of plats. It should be studied line by line and word by word.

PLAT LAW.

(§1473) SECTION 1. Whenever any town, city, village or addition thereto, shall be laid out, or shall be altered or vacated as hereinafter provided, within this State, the proprietor or proprietors thereof shall cause a true map or plat thereof to be made by a civil engineer, surveyor or other competent person. Such map or plat shall in every case be made on a scale showing not more than two hundred feet to an inch, on sheets of good muslin-backed paper, eighteen inches by twenty-four inches in size. There shall be written upon the paper on which said map or plat shall be made, a full and detailed description of the land embraced in said map or plat, showing the township and range in which such land is situated, and the sections and parts of sections platted, and containing the name of the town, city, village or addition platted, the name or names of the proprietor or proprietors thereof, and of the engineer, surveyor, or person making said map or plat, with the date. The same shall be signed by such proprietor or proprietors and their wives, and engineer, surveyor or person making the same, and shall be witnessed and acknowledged by the owners as deeds conveying land are required to be witnessed and acknowledged. The sections and parts of sections platted shall also be designated by lines drawn upon said map or plat, with appropriate letters and figures, and in case of a subdivision of lots or blocks of a previous survey, the outlines of the original or previous lots or blocks so subdivided shall be designated by lines drawn upon said map or plat, and shall be marked with appropriate letters and figures. There shall also be on such map or plat a plain designation of the cardinal points, and a correct scale. Such map or plat shall be recorded in the office of the Register of Deeds for the county in which the land is platted is situated. Before such plat shall be recorded, and before any copies are made therefrom, the person making the same shall forward the original plat to the Auditor General of the State, who shall approve of the same whenever such plat shall conform, in his opinion, to the requirements of this act, and shall return the plat to the person who forwarded it, with his approval endorsed thereon. For the purpose of such recording the said proprietor or proprietors shall cause to be made by a civil engineer, surveyor or other competent person, on the same scale, and on paper of the same size and quality as that on

which the original map or plat is required to be made, an exact copy of said original map or plat with the detailed description, signatures, witnesses, acknowledgment and endorsement of approval as above specified. When such map or plat shall conform, or shall be made to conform, in all respects to the requirements of this act, the said register, and said engineer, surveyor, or person who made the same, shall each carefully compare said copy with said original map or plat, and if correct, or when made correct, it shall be certified by the said register and said engineer, surveyor, or person who made the same, who shall certify that they have carefully compared the same with said map or plat, describing it, and that it is an exact copy thereof and of the whole of such original map or plat. The said register shall then securely fasten the said copy in a book of the proper size for such paper, so that it shall not be folded, which book shall be strongly bound in leather and provided at the expense of the said county, and such copy, so fastened in said book, shall be held and taken to be a record of said map or plat, with like effect as if said map or plat had been actually transcribed by said register in a book in his office; but in no case shall any such map or plat be recorded until it shall be made to conform to all the requirements of this act, nor until such duplicate shall be an exact duplicate of said original map or plat as approved by the Auditor General, and for any willful violation of this provision by a Register of Deeds, he shall be liable to a penalty of ten dollars, and shall also be liable to pay all damages which any person may sustain by reason thereof, to be recovered in an action of trespass on the case. The register shall certify on such map or plat the time when it was recorded as aforesaid, with a reference to the book or page where recorded. He shall note on the record the time when made, and shall keep a separate index of maps or plats, in which he shall enter alphabetically, the name of every town, city, village, or addition, the map or plat of which shall be recorded by him, with a reference to the book and page where the same shall be recorded. There shall be made a true copy of the record of such map or plat so recorded, on paper of the same quality and size as above prescribed and on the same scale, which copy shall be certified by the said register and engineer, surveyor, or person making the same, who shall certify that they have each carefully compared the same with the record, and that it is a true transcript therefrom, and of the whole of such record. Such copy so certified shall then be delivered to the Auditor General of this State, who shall file the same in his office. The Auditor General shall keep an index in which he shall enter, alphabetically, the name of every town, city, village, and addition, a copy of the record of the map or plat of which shall be filed in his office, the date of filing the same, and whatever else he may think necessary to facilitate reference thereto. On delivering such copy to the Auditor General, the person delivering it shall pay into the state treasury, to the credit of the general fund, the sum

of one dollar. The original map or plat, with the certificate of record endorsed thereon, the record thereof made as aforesaid, or a properly certified transcript of such record shall be received in all courts of this state as *prima facie* evidence of the making and recording of such map or plat in conformity with the provisions of this act, and the copy of such recorded map or plat filed in the Auditor General's office, or a properly certified transcript thereof, shall be received in all courts of this state as *prima facie* evidence of the above matters, and also the filing of said copy in the Auditor General's office. If any person or persons shall sell any lot or lots within any such town, city, village, or addition, before the map or plat thereof shall be recorded and the copy of the record thereof filed as aforesaid, he or they shall forfeit and pay the sum of ten dollars for each lot so sold. For all services by this act required to be performed by a Register of Deeds in respect to any such map or plat brought into his office for record, the said register shall be entitled to receive the sum of two dollars, which shall be paid by the proprietor or proprietors of the ground platted: *Provided*, That in all cases where the proprietor or proprietors of any piece or pieces of land shall have caused the same to be laid out and platted as a city, town or village, or as an addition to a city, town, or village, or where the proprietors have caused such city, town or village lots to be deeded by metes amd bounds and courses, and have failed or neglected to have a plat thereof made and recorded in the office of the Register of Deeds of the county in which such land is situated, the surveyor or assessor of the township, city or village in which such land is situated shall, when authorized by the township board of such township, or by the common council or board of trustees of such city or village, cause a map or plat of said city, town, village, or addition to be made under his hand and seal, properly acknowledged by him, and showing by reference to this act the authority for the same, and have the same properly recorded in the office of the Register of said Deeds, and filed in the Auditor General's office, as hereinbefore provided, and such plat or map when so recorded and filed, shall be treated in respect to the assessment, collection and return of taxes, and the sale of said lands for delinquent taxes, as if the same had been made by the proprietor or proprietors: *Provided*, That such proceedings shall not interfere with vested rights: *Provided further*, That the expense of making said plat or map when done by the supervisor or assessor according to the provisions of this act, shall be paid by the township, city, or village in which such plat is located.

(§1474) SEC. 2. That such maps or plats as are by this act required to be recorded, shall particularly set forth and describe such portion of the government survey as is intended to be platted, and when said premises are not included in the legal subdivisions of the government surveys, then the boundaries to be defined by metes and bounds and courses. Said maps or plats shall also particularly set forth and describe all the

public grounds, except for streets and alleys, by their boundaries, courses and extent, and all streets and alleys by their courses, lengths, widths, names or numbers by writing or figures upon that portion of the map or plat intended for those uses. And all the lots intended for sale may be numbered, either by progressive numbers, or if in blocks, progressively numbered in each block, and the blocks progressively numbered or lettered. Where all the lots of any block are of the same dimensions, it shall be sufficient to mark the precise length and width upon one tier thereof; but all gores, triangles, or other lots, which are not either squares or parallelograms, shall have the length of their sides plainly defined by figures.

Permanent monuments shall be located in the ground at all angles in the boundaries of the land platted, and at all the intersections of streets, or streets and alleys, as shown on the map or plat, and when there are permanent objects in the vicinity of such monuments the bearings and distances of such objects shall be noted. The character of the monuments and the bearings and distances of such witness points or objects shall be distinctly given in the most convenient manner on the plat. The surveyor or engineer making such plat shall certify that the plat is a correct one, and that the monuments described in it have been planted as therein described. The map so made and recorded in compliance with the provisions of this act shall be deemed a sufficient conveyance to vest the fee of such parcels of land as may be therein designated for public uses in the city or village within the incorporate limits of which the land platted is included, or if not included within the limits of any incorporated city or village, then in the township within the limits of which it is included in trust to and for the uses and purposes therein designated, for no other use or purpose whatever.

Sec. 135, Act No. 206, Laws of 1893, as amended by Act 154, Laws of 1895. When any deed, land contract, plat of any town site, village, or addition to any town site, village plat or city, or any other instrument for the conveyance of title to any real estate, is presented to the register of deeds of any county in this State for record or filing in his office, he shall require from the person presenting the same a certificate from the Auditor General, or from the county treasurer of the county, whether there are any tax liens or titles held by the State, or by any individual, against such piece or description of land sought to be conveyed by such instrument, and that all taxes due thereon have been paid for the five years preceding to the date of such instrument, and in default of the presentation of such certificate he shall not record the same until such certificate is secured and presented. The register of deeds shall note the fact upon said deed that said certificate has or has not been presented to him when such instrument is presented for record, and in case the person presenting such instrument shall refuse to procure such certificate, he shall endorse that fact upon said instru-

ment, over his official signature, and shall refuse to receive and record the same: *Provided*, That the provisions of this section shall not apply to the filing of any town or village plat for the purpose of incorporation, in so far as the land therein embraced is included in a plat already filed in the office of the register of deeds, or in so far as the description of lands therein is not changed by such plat, nor to the filing of any copy of the town, village or city plat in case the original plat filed in the office of such register of deeds has been lost or destroyed, nor to any sheriff's or commissioner's deed executed for the sale of lands under any proceeding in law, or by virtue of any decree of any of the courts of this State, nor to any deed of trust by any assignee, executor or corporation executed pursuant to any law of this State; nor to any quit claim deed or other conveyance containing no covenants of warranty; nor to any land patent executed by the President of the United States, or the Governor of this State, nor to any tax deed made by the Auditor General; nor to any deed executed by any railroad company conveying its right of way, provided such deed is accompanied by a certificate of the Auditor General showing that all specific taxes due from said railroad company have been paid, to and including the year in which such deed is executed. A violation of the provisions of this section by any register of deeds shall be deemed a misdemeanor, and upon conviction thereof he shall be fined not to exceed one hundred dollars, and he shall further be liable to the grantee of any instrument so recorded for the amount of damages sustained, to be recovered in an action for debt in any court of this State.

## A REDETERMINATION OF THE ELECTRO-CHEMICAL EQUIVALENT OF SILVER.[1]

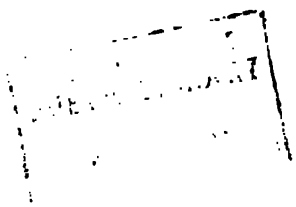
K. E. GUTHE.

At the International Congress of Electricians in Chicago, 1893, a new system of practical electrical units was proposed by the chamber of delegates and unanimously accepted. In the following year these unit were made legal by Act of Congress. By this system an ampère is defined as that current which, when passed through a solution of nitrate of silver in water deposits silver at the rate of 0.001118 gramme per second. Certain specifications with respect to the solution and the material, size and shape of the electrodes must be followed. This definition of the ampère is founded on the fundamental units of length, mass and time and was intended to be one-tenth of the absolute unit of current.

One of the most interesting problems presenting itself is the determination of the mechanical equivalent of heat by measuring the heat effect of

(1) Abstract of a paper which appeared in Physical Review, Dec. 1898, VII, pp. 257-282.

Electro-Dynamometer Used in Redetermination of the Electro-Chemical Equivalent of Silver.



a current, i. e. h = C²Rt. Accurate experiments of this kind were undertaken in 1881 by Griffith[1] and in 1885 by Schuster and Gannon[2], but these physicists found that the value of the mechanical equivalent of heat as measured by the electrical method exceeded, by about one-ninth *per cent*, that which Rowland had previously found in his classical experiments by direct conversion of mechanical into heat energy[3].

To explain this discrepancy a great deal of labor and time was spent by the comparison of the thermometers used in the different investigations and the conclusion, finally arrived at, was that the discrepancy is not one of thermometry, but is rather due to an error in the standards used.[4] That it was considered of great importance to settle the question is shown by the fact that the English Association in 1897 appointed a committee on standards which was to redetermine the accurate value of the unit of current. This committee received last summer a large appropriation for the building of a new current-balance for this purpose. The American Association for the Advancement of Science appointed a similar committee, an secretary of which Professor Carhart was elected. He secured for us a grant from the Association and helped us from the beginning by his advice and the great interest he showed in the progress of the investigation.

Professor Patterson proposed in the fall of 1897 a new method for measuring the electro-chemical equivalent of silver and kindly asked the writer to join forces with him in the practical working out of his idea. The method differs in important points from those employed heretofore. In all former determinations only two types of instruments were used, the current-balance and the tangent-galvanometer. In the former the final values depend upon the accurate knowledge of the acceleration due to gravity, in the latter on that of the horizontal component of the earth's magnetic field. Lord Rayleigh and Mrs. Sidgwick[5] found by the former method 0.00111794 grm. and Fr. and W. Kohlrausch[6] by the latter 0.001118[3] grm. for the electro-chemical equivalent of silver. In spite of the close agreement of these two values later experimenters arrived at less concordant results. Pellat and Potier[7] in France found 0.0011191 grm., Kaspari[8] in Germany, 0.0011174 grm., and finally Kahle[9] at the Imperial Physical Institute at Berlin 0.0011182 grm., using the same instrument as the former observer, i. e. a very accurate current-balance.

Our plan was to make ourselves entirely independent of g or H by balancing the moment of the movable coil of an absolute electro-dynamometer due to the electro-dynamic action between the two coils against the torsional moment of the suspending wire, when twisted through a certain angle. By this method we reduced the measurements necessary

(1) Phil. Trans. A. 184, A., p. 291, 1893.
(2) Phil. Trans. 186, A., p. 413, 1895.
(3) Proc. Am. Acad., 35, p. 71, 1879.
(4) Phys. Review, 6, p. 225, 1898.
(5) Proc. Roy. Soc., 60, p. 144, 1896.
(6) Wied. Ann. 27, p. 1, 1886.
(7) Journ. de Phys., 4, p. 561, 1896.
(8) Wied. Ann. 55, p. 400, 1895.
(9) Zeitschr. f. Inst. Kunde 1898, p. 170.

for the determination of the ampère directly to measurements of the fundamental units.

The wooden frame of the fixed coil of the electro-dynamometer was constructed in the machine-shops of the University and the instrument completed by our former mechanician, R. H. Miller. The fixed coil consists of 576 turns of copper wire in a single layer and has a mean length of 41.633 cms. and a mean diameter of 48.116 cms.; the movable coil of 8.805 cms. mean length and 10.0187 cms. mean diameter, has 45 turns of a flat copper strip wound on a hard rubber cylinder which was suspended at the center of the fixed coil by a single phosphor-bronze wire 0.0355 cm. in diameter and 100.5 cms. long. The dimensions of the electrodynamometer were selected in such a way that it was relatively easy to calculate the electromagnetic effect of the two coils upon one another when a current is flowing through them. The current went through the two coils in series and was led into the movable coil through two mercury cups below and in line with the suspension. The lead wires from the terminals of the fixed coil were carried along the surface, parallel to the axis, to binding posts at diagonally opposite corners of a square and the lead wires from the suspended coil were brought out to the other corners of this square. The error due to a small asymmetry was eliminated by reversing the current in the fixed coil. The suspending wire was soldered into small brass cylinders at both ends, the clamping of the wire being done by means of these so that the length of the wire remained constant throughout the experiment. Of greatest importance was the fact that the wire showed only a very slight elastic fatigue, whose influence we were able to eliminate almost entirely.

The whole investigation was naturally divided into two main parts.

(1) The determination of the torsional coefficient of the suspending phosphor-bronze wire;

(2) The measurement of a current in terms of the silver deposited by it.

(1) In the first case we had to make a large number of determinations of the period of the wire when a brass cylinder of known dimensions and weight was suspended by it, being held firmly by one of the small cylinders soldered permanently to the ends of the wire. The weight equalled very nearly that of the suspended coil of the electrodynamometer so that the wire was under the same stress as well during this part of the investigation as during the second. The time of vibration which was found by the method which is in common use in our laboratory, is practically a linear function of the temperature, varying from 11.9679 seconds at 20.19° to 11.9851 seconds at 26.89° C. The logarithmic decrement was found to be extremely small. All these measurements were taken with the system in a vacuum tube so as to eliminate the possible error due to friction in air.

From these determinations and the dimensions of the coils we obtain by calculation as the theoretical value of the current necessary to balance the torsional moment due to a twist of $2\pi$, of the wire at the temperature $t°$,

$$I = 0.95158 \text{ ampère.}$$

(2) Since the instrument was so sensitive that it was impossible to keep the current constant at the value necessary for a balance, we had to divide this part of the work into two distinct subdivisions. First, we found by Poggendorff's Potentiometer method the ratio between the E. M. F. of two Standard Cells immersed in a large water-bath and the potential difference at the terminals of a coil of manganin wire, when a current flowed through it, which just balanced the torsional moment of the suspending wire of the electrodynamometer due to one complete twist of the torsion head.

Let I be the calculated theoretical value of the current,

E the E. M. F. of the Standard Cells,

$R_1$ the resistance necessary to balance E,

$R_2$ the resistance necessary to balance the Pot. Diff. due to I,

R the resistance of the manganin coil,

then

$$I = \frac{R_2}{R_1} \frac{E}{R}$$

Secondly, by the same method the E. M. F. of the cells was balanced against the Pot. Diff. over the manganin resistance due to the silver depositing current.

Let I' be this current,

$R_1'$ and $R_2'$ the resistance necessary for the balances,

E and R the same as before,

then

$$I' = \frac{R_2'}{R_1'} \frac{E}{R}$$

The silver deposited by the current I' is

$$q = z\, I'\, t \text{ grammes,}$$

where z is the electro-chemical equivalent of silver,

but

$$I' = I\, \frac{R_1}{R_2} \frac{R_2'}{R_1'}$$

therefore

$$Z = \frac{q}{It} \frac{R_1'}{R_1} \frac{R_2}{R_2'}$$

We can thus determine the electro-chemical equivalent of silver without knowing the absolute value of the E. M. F. of the cells or the absolute resistance of the manganin coil, the only necessary condition being that the resistance boxes used for obtaining the balances were well calibrated

relatively. By a number of independent experiments we found as the *value of the electro-chemical equivalent of silver*

*0.0011192 gramme per ampère per second,*

a value somewhat larger than the accepted. Kahle's results, though somewhat smaller, would give 0.0011190 gramme, if his silver nitrate solution had been treated the same way as ours. The silver deposit from a silver nitrate solution varies indeed according to the previous treatment of the solution and on the conditions of the kathode. Our value seems to show that the accepted value of the unit of electric current is a little too small; so here we have found a satisfactory explanation for the discrepancies found for the mechanical equivalent of heat, alluded to above.

The E. M. F. of the Clark cell is a much better standard than the silver voltameter, since it has a very constant value. It would have been easy to determine its E. M. F. directly, had we known the actual resistance of the manganin coil. A simple calculation, using Glazebrook's value, which is based on the electro-chemical equivalent of silver = 0.001118 grm. gives us for the *E. M. F. of the Clark cell 1.4327 volts at 15° C*, while Kahle found 1.4328 volts. The American Association granted a second appropriation for the continuation of the work. Two standard resistances from the Imperial Physical Institute at Berlin are now on their way here, and Professor Carhart has made two standard Clark cells, according to legal specifications. He and the writer intend to follow out the work described above by determining directly the E. M. F. of the legal form of the Clark cell.

## USE OF ELECTRICITY IN A GAS PLANT.

H. G. FIELD, '93.

At first thought it might well be treated as a joke to suggest the use of electric lights to illuminate the works of a gas generating and supply company.

On the contrary, electric lighting may be used in such a plant to great advantage. The writer has recently planned and supervised the installation of a small electric plant for lighting the works at Station A, of the Detroit City Gas Company. A brief description of this equipment and its special utility may prove interesting.

The dynamo is a Crocker-Wheeler bi-polar belted machine with a rated capacity of forty amperes at one hundred and twenty-five volts. It is driven by a White & Middleton gas engine, rated at nine brake horse power. This engine furnishes power from its main belt pulley to drive a line shaft, from which are belted various machines, such as drill presses, lathes and blowers for general shop and forge purposes. An

auxiliary belt pulley is belted to the other fly wheel to drive a counter shaft, from which the dynamo is belted. The counter shaft is provided with tight and loose pulleys to allow the dynamo to be run or remain idle as desired. A fly wheel is attached to this counter shaft to assist in maintaining the dynamo at constant speed.

The marble switchboard contains an ammeter and a voltmeter of the Weston round pattern, a field rheostat for dynamo, a Fisher single pole vertical operating circuit breaker, voltmeter and ground detector switches, pilot and instrument lamps, and switches for controlling the various feeders, all protected by fuses.

The buildings and portions of the grounds lighted are principally such as would prove dangerous on account of possible explosions if lighted by gas or exposed to flame. The feeders run mainly outside of the buildings, and supply current at various distributing centers to a total of about one hundred lamps, of from four to thirty-two candle power. At the centers of distribution are cabinets which contain cut-outs with fuses to protect the various circuits. Especial care was taken to carefully seal all openings leading from these cut-out cabinets into rooms where danger might arise from gas explosion resulting from the blowing of a fuse, and these cabinets are ventilated into the open air.

The dangerous departments include the Pintsch compressor room and tank house; the natural, coal and water gas purifier cellars, and ground floor rooms, and the ammonia room. To avoid sparks in these rooms, keyless sockets are used and the lights are operated by switches outside, either provided with special waterproof boxes, or placed inside of cabinets.

The inside wiring is mostly of the exposed or open character, except where subject to injury by employes, in which cases molding is used to protect the wires.

Long extension cords with rubber, jute and cotton covering, and provided with waterproof sockets and heavy lamp guards, are used for portables to facilitate inspection in case of trouble in tanks, purifiers, valves or inaccessible appliances.

Where it was formerly necessary to work in the dark in case of gas leakage in any department, it is now possible to turn on electric lights from without, enter and make repairs by the aid of electric light, and without danger from explosions.

As auxiliary electrical equipment may be mentioned a storage battery of three cells of type D 7 Chloride Accumulators used in connection with a spark coil for the gas engine igniter in starting up. This battery also serves to operate an electric counter located in the coal gas generator room. This counter is connected with the large main meter near the offices and registers in view of the operators, the amount of gas passing through the meter.

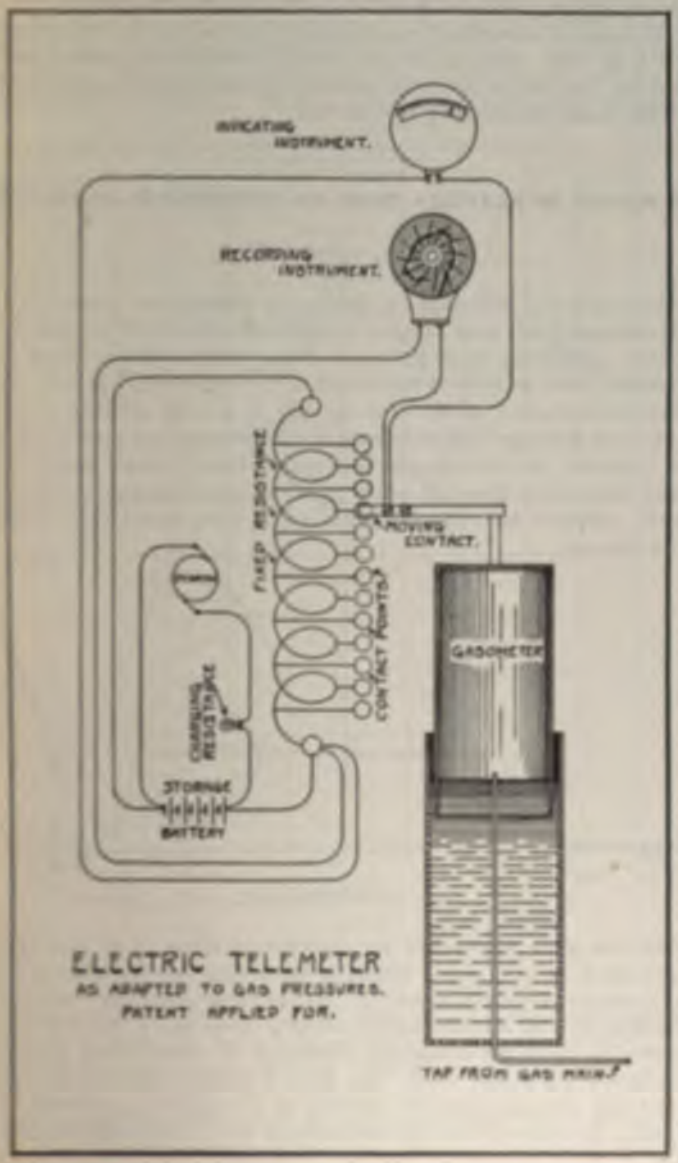
An electric telephone system with seven instruments, furnishes an easy means for the superintendent to communicate with the various departments. Some difficulty was found at first, due to coke and coal dust, which collected on top of the magneto boxes, and short circuited the electrical contacts. Covers were afterwards provided for these contacts thus effectually stopping the trouble.

A new and somewhat novel electrical device for indicating at the works the exact gas pressure in the street mains, at the office building over two miles away, has been in successful service for the past four months. It was invented and designed for this special service, and a patent has been applied for to cover its application to indicating or recording at a distance any pressures, positions, volumes or changes of pressure or position. The application may be made equally well to steam or any vapor, gas or solid.

The indicating instrument consists of a voltmeter to measure the drop of potential over a circuit of practically fixed resistance, over which a current of constant value is passing. The current is provided by a storage battery and is maintained constant by being continuously charged by current from a dynamo. The current from the dynamo is regulated by lamp or other resistance, so that the charging current is just enough in excess of the battery current to provide for the loss in the battery according to its efficiency. A sliding contact is attached to the bell of a gasometer at the Gas Office. This sliding contact connects with the various segments of a commutator connected at frequent points on the resistance coil. These points are spaced uniformly with respect to the drop in potential. As the contact point moves up or down, due to increase or decrease of pressure in the gasometer, the drop in potential is greater or less, and is so indicated on the voltmeter at the gas works. The voltmeter is calibrated to read in terms of gas pressure as so many inches of water head. The accompanying diagram illustrates the connections and circuits as applied to both an indicating and a recording voltmeter.

In addition to these applications of electricity in a gas plant it is now proposed to operate in the basement of the office building of the Gas Company, another dynamo, directly connected to a small engine to be likewise operated by natural gas. This is to be an exhibition plant to illustrate the possibilities of using natural gas to advantage in driving dynamos for light and power. Current will be supplied to several incandescent lamps to illuminate the exhibit, to arc lamps and to a motor which will operate a pipe cutting machine, a drill press, an emery wheel, a grindstone and an exhaust fan to ventilate the meter testing and repair department. A dozen or more electric fans to ventilate and cool the offices will also be run by current from this same dynamo.

The possibilities of such plants on a good commercial basis are increasing rapidly with the many improvements in the manufacture of close




ELECTRIC TELEMETER
AS ADAPTED TO GAS PRESSURES.
PATENT APPLIED FOR.

regulating gas engines, and especially at the existing low rates for natural gas. The cost of operation for such plants is so low that the Gas Company claims that with water gas at more than double the present price of natural gas, the cost of operation would still allow a good margin to compete with steam plants using coal for fuel.

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## COAL MINING IN ALABAMA FROM AN ENGINEERING STANDPOINT.

HENRY GEISMER, '97.

The coal in the Birmingham district of Alabama is bituminous coal and is comparatively easy to mine as it lies in nearly flat beds, the average dip of the seam being about thirty minutes. Another feature that makes the coal very easy to mine is the height of the coal seams above the water courses of the district, as the coal *outcrops* in a large number of places. It is at these outcrops that nearly all of the openings are made. In a few cases, however, the outcrops are so situated that it would be impossible to build railroads to them, in which case one must resort either to a slope or shaft. Figure 1 is a cross section of a mountain showing the coal seam and its outcrop.

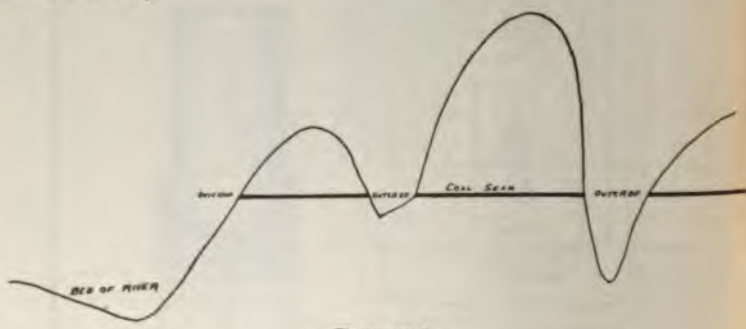


FIGURE 1.

The first work required of an engineer in opening up one of these mines is an outcrop survey. Running an outcrop line is similar to tracing a single contour around a mountain. Find a place where the coal outcrops, then either with an aneroid barometer or a level carry the elevation of the outcrop around the mountain, allowance of course being made in the levels for the dip of the seam. In some localities the coal *bench* is so marked that after one finds the outcrop at any place on the side of the mountain, the outcrop line can be followed by simply following the coal bench.

Figure 2 is an outcrop map of a township. After the outcrop map is made, the place for the main opening or openings is decided upon, and then all of the entries are plotted on the outcrop map. The openings are always made, if possible, at the lowest place in the seam, and the work is then carried to the raise. This is necessary on account of drainage; it

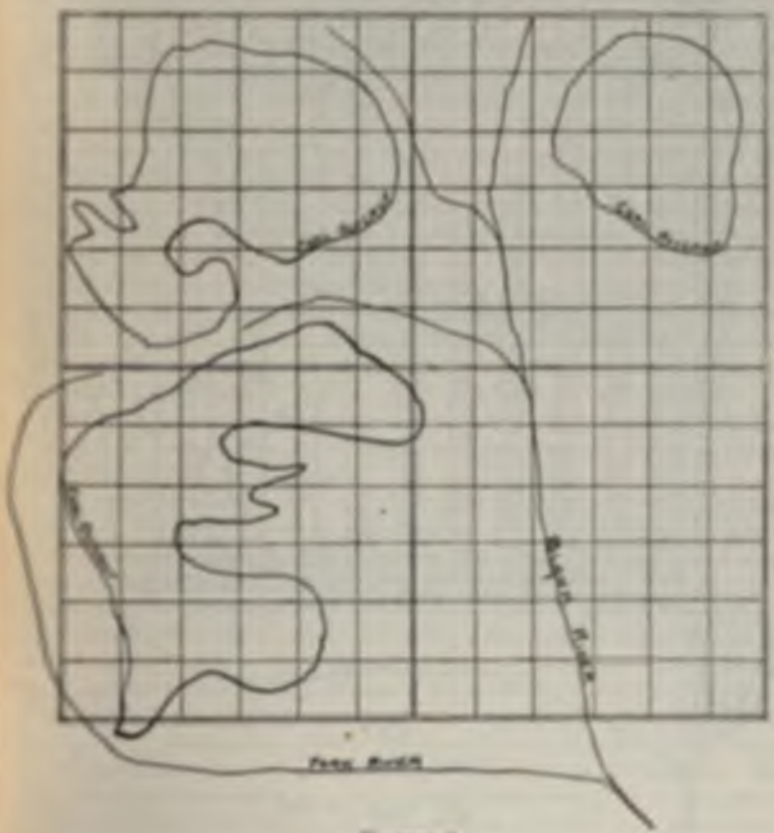

FIGURE 2.

also gives the loaded cars the benefit of the down grade. The opening is always made near a ravine in drift mines, as it is the ravine that the railroad engineer must look to for his roadbed from the mountain to the valley below.

The method of working the coal is known as the pillar and room system. A main or face entry is driven clear through the territory. Along

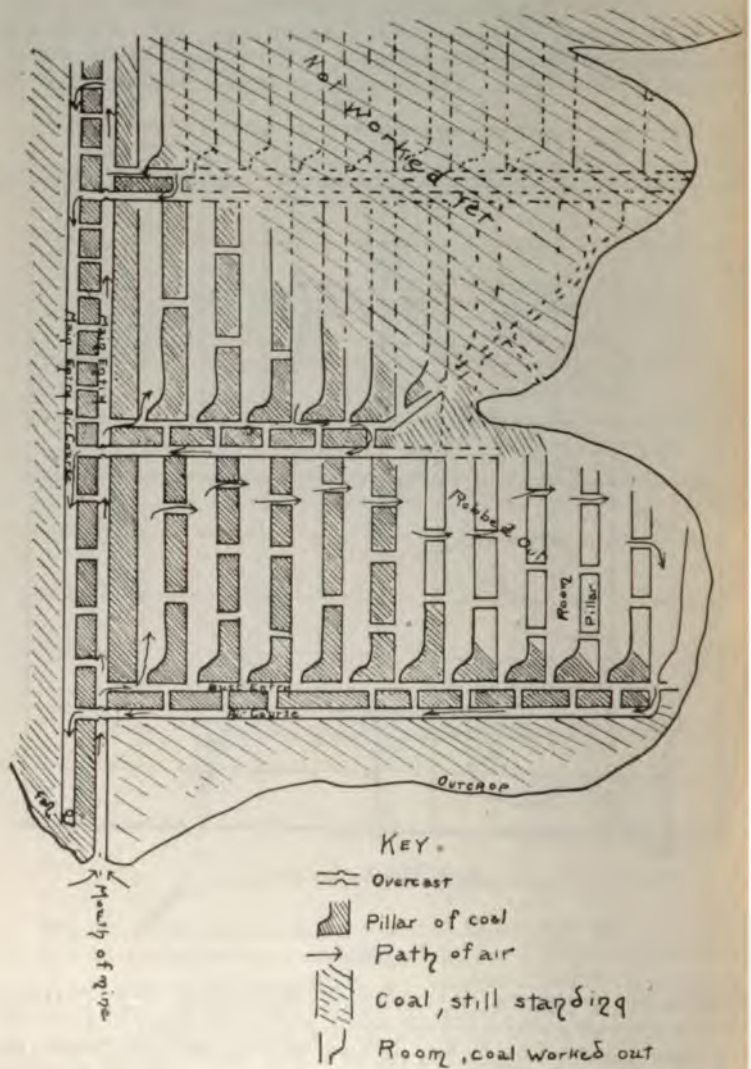
Not worked as yet
Robbed out
Room
Pillar
Outcrop
Mouth of mine
KEY.
Overcast
Pillar of coal
Path of air
Coal, still standing
Room, coal worked out

FIGURE 3.

a entry at distances of about three hundred feet cross or butt
re turned off which are driven through the territory but in a
almost at right angles to the main entry. It is from these butt
hat the rooms are turned off. The block of coal between each set
entries is split up by rooms some twenty-five feet wide, separated
h other by *pillars of* coal some fifteen feet wide. The relative
f the room and the pillar depends on the rock above the coal.
f the rooms off from one entry are driven through to the next
e miners start at the last pillar on that entry and mine out all of
in it. As the coal in the pillar is pulled down wooden props are
support the roof. It is necessary to leave the pillars standing
entry has been driven to its limit in order to prevent part of the
falling and shutting off the entire entry. Figure 3 is a map of
ings of a mine, and shows the method of ventilating the mine.
has two vertical cleavage planes or cleats, as they are called, at
gles to each other, or nearly so. One is called the *face* of the
the other the *butt*. The working face of the coal must be
the face as the coal is most easily broken in planes parallel
face; this makes it necessary that the working or secondary
e parallel to the face, or nearly so. The face thus limits the
of the entries.

r the directions of all of the entries are decided upon and located on
the engineer is depended upon to see that the work is driven
g to the original plans.

men at work in the entries are kept in line by means of centers
. Centers are points in the roof some three feet apart that admit
or plum bobs being suspended from them. The best and most
center is a horse shoe nail with a hole punched in its head,
into wooden plugs in the roof of the entry. A new set is needed
ery two hundred feet. To put up a new set the engineer sets up
e of the spads of the last set, then puts his instrument in the line
try by back sighting to one of the spads in the next to the last set.
ood fore and back sight is an ordinary plumb bob with an extra
ad. Suspend the plumb bob from the center and hold the flame
er's lamp behind the cord in line with the line of the entry. The
at the instrument man sees has a black streak down the center
it is this streak that he is to bring to coincide with his vertical
e. After the center is driven into the roof the instrument man
the distance between it and the last set and then plots it on the
p. This allows the company at any time to find out just how fast
is progressing.

des laying out the work the engineer is supposed to solve all
that come up in reference to drainage, haulage and ventilation.
tilation of the coal mine is a problem in itself that calls for a

great deal of engineering skill and judgment. Think of an underground city several miles square, filled with hard working men and you get some idea of the difficulty and importance of ventilation. But in a paper of this size one could not take up any of the real problems of the mine.

EXPLANATION OF TERMS USED.

*Bench.* The rock above and below the seam of coal is much harder than the coal, and unlike the coal is hardly affected by exposure to the air. As the coal disintegrates the rock above it breaks off while the rock below remains firm; this leaves a break in the side of the hill that is called a bench.

*Entry.* A haulage way in the mine.

*Outcrop.* The part of the seam that is exposed.

*Overcast.* A large bridge or crossing built over an entry to permit the air from an intersecting air course to pass over the entry.

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## REMINISCENCES.

FRANK P. DAVIS, '76.

Most engineers learn sooner or later that a thorough knowledge of the everyday things of life, and plenty of common sense contribute quite as much to success as theoretical attainments. If an engineer is called upon to do work on the frontier in uninhabited regions it is frequently as necessary that he should be a cook, packer, boatman and doctor as that he be a good engineer.

It is with these thoughts in mind that the writer ventures to present for the perusal of the younger members of the profession some reminiscences culled from an experience of thirty years. In March, 1881, the writer reported to the Chief Engineer of the Denver & Rio Grande Western Ry., at Salina, Utah, to take charge of a party on location. The party was made up in the east with the exception of chainmen, axmen, packers and cooks. They were to be hired at Salina.

We were to cross the Wahsatch Mountains by way of Salina pass at an elevation of seven thousand five hundred feet. In places the trail led over gulches filled with snow to a depth of from twenty to thirty feet. As soon as the snow began to soften in the spring this part of the trail would become impassable. It was therefore deemed important that we get away as soon as possible. With this in view all the help and outfit to be provided there had been engaged before we arrived. We were told that our cook and packer were experienced men who understood their business. The mules had never been packed, but it was thought that by having them led for a day or two there would be no trouble.

It was my first experience in packing and I began to wonder how a sheet-iron cook stove and a large drawing table were to be packed on a mule's back, but wisely held my peace.

The morning of our departure found us up bright and early, with tents down and bedding done up ready for packing. Immediately after breakfast the mules were brought out and the pack saddles adjusted. Our packer then proceeded to show his skill. The mule was held while he piled on bundles until he thought the load was sufficient, when he lashed them by passing a rope over the bundles and under the mule's belly until one could hardly see either mule or bundles. I have since heard of and seen squaw packing, but I am sure any squaw would drown herself if accused of any such packing. The mule was turned loose and in about two minutes started back to the corral without any pack. Night found us without a mule packed. Our proficient packer was no good. That night an experienced packer came in and the next morning instructed us in the mystery of the "diamond hitch," and showed us how to properly balance a pack so that it would ride easily on the mule. The Chief Engineer concluded to give us a four mule freight team, and keep part of the pack mules, so that by eleven o'clock we were loaded and the train started, each mule being led by a man. I was detailed a couple of hours and followed on horseback. Imagine my surprise and indignation on finding the outfit out about four miles with mules unpacked, enjoying themselves over a feast of canned fruit. It took some vigorous language to convince them that they would find the value of all supplies thus broken into charged up against them on the first pay-roll. There was no further trouble with that party on account of provisions being molested.

Our cook proved to be but little better than our packer. The second morning I got out early and found it had snowed about four inches during the night. There was no fire, the dishes of the night before were where we had eaten supper, unwashed, with knives, forks and spoons scattered around on the ground under the snow. The cook was fast asleep. It only took that cook about fifteen minutes to get up, dress, make up his pack and get out of camp on the back track. The writer cooked breakfast. That day I was fortunate in discovering that one of my men was an excellent cook.

That morning the rodman got up with a severe case of mountain fever. He was a very sick man but we could not delay, so I gave him my saddle horse and he managed to pull through the day, taking large doses of quinine to keep him up. The next day he had to take to the wagon which nearly jolted the life out of him over the rough trail, but he was too weak to sit on a horse. For three days he rode on the wagon until we got near the summit where I was to halt and send back the team and mule for more provisions. Our scanty medicine chest had nothing for fevers so we made a strong decoction of the sage brush of the desert and

gave it to him in large quantities, as hot as he could drink it. In this way we kept him in a profuse perspiration until we broke the fever.

While at this camp the writer went out to hunt for deer, which were plenty. A drove of six or eight was found huddled up behind a clump of pinon pines. There was a fair shot at the head of one at a distance of less than one hundred feet, but there were two standing so that their hind quarters overlapped. Thinking to get two at one shot I drew on the two and fired. Both went down but both jumped and went down the mountain side on a run. I followed those deer all day and went to camp at night without any game. Take a sure thing when you have it.

The next July and August we were hauling all our water from twenty to forty miles, with the thermometer from 100° to 110°. At the same time we were walking from three to six miles to and from our work over a very rough mountain country, besides doing a full day's work in the field and keeping up our map and profile at night. Frequently the cook would hoist a lantern on the end of a wagon pole to guide us to camp. The country was such that we could not get our wagons with water nearer. Finally we adopted the plan of having the cook come out each afternoon with provisions and water kegs packed on mules, and we would stop at the end of the line for the night. In this way we did not go to camp for a week.

While on this work the writer made an exploration through the lower Price River Canon and a portion of the Green River Canon. This was probably the first time a white man went through the latter canon on horseback. Major Powell had been through with boats. The trip was not as difficult as was expected, and well repaid the hardship. For three days we had a herd of deer of from twenty to thirty ahead of us, most of the time within easy rifle range. There was not a spot where they could get out of the canon. We only killed three, what we could use on the trip.

The next spring the writer accepted a position to take charge of a party on location on the Mountain Division of the Canadian Pacific Railway. A friend and I were to join a party from Winnipeg at Fargo, on the Northern Pacific Railway. At this time the whole Red River country was under water, and our train from Fargo west ran for miles over track which was entirely submerged; as a consequence, instead of reaching Bismarck at dark we were about ten hours behind time and rode all night. During the night it became evident that two young men who occupied the seat behind me were members of the party who had come from Winnipeg. They were bewailing their hard fate at having to ride all night in an ordinary coach. "Had they known they would have to endure such hardship they would never have come."

About a month later when crossing an alkali flat on the trail north from Fort Benton our mules were stampeded by a severe hail storm, and with our wagons stuck in the mud we had to make camp for the night on

ground where there was water wherever one stepped. There was not a bunk or anything to be had to keep the blankets above the ground, and those two young men would have considered a car a palace that night. From Bismarck we took the first steamer up the river to Fort Benton. The distance is about twelve hundred miles, and we made it in seventeen days. Most of the time the weather was fine and in some parts the scenery magnificent, so that we enjoyed it greatly.

The trip from Fort Benton to Fort Calgary, a distance of about 320 miles, as I remember it, was made with prairie schooners. Three wagons were coupled together like cars and each train drawn by six teams of mules. We averaged about twelve miles a day. The weather was fine, and trout fishing in the small streams good. It was not at all uncommon to see a man come into camp at night with a string of from ten to thirty fine trout. Prairie dogs and rattlesnakes abounded along the trail. This part of the journey was enjoyed by all. We had been told there would be pack horses and packing outfit for us at the base of the mountains. There were three parties of us and only horses and outfit enough for two, so as the other parties were to go over the mountains to the west side and my party to work on the east side, they were outfitted first, and I had to rustle for horses and pack saddles. We brought unbroken horses and had to turn to and make pack saddles. To do so we had to send sixty miles to get screws and rings. This ride of one hundred and twenty miles was made in two days, and every one who could use a knife or any other tool was put to work on the saddles. Fortunately we had a packer who had been in the business for years and was a first class man. As soon as we had a few saddles we began to break in the horses. We found one which objected, and after two days was still untamed. Our young men thought it would be better to ride him first. One after another they tried, but he was unridden. We finally filled sacks with wet sand and put a load of about four hundred pounds on him and conquered, but for a week he had to be blindfolded and led on the trail.

Our route led up the magnificent valley of the Bow River, following an Indian trail which wound around and over fallen timber, and was hardly passable for heavily laden animals.

Our transportation was so limited that the men were only allowed to take their bedding and an extra pair of socks on the first trip. This had to last for two weeks.

The morning of the third day out we came to Swift Current Creek, a stream about two hundred feet wide and from two to three feet deep. The current was so swift it would sweep a man off his feet, and the water very cold. The only way to ford it was for each man to twist his hand into the tail of one of the pack horses and take the halter of the following horse in the other hand, and then be towed over. All got safely over but were chilled to the marrow. About two hours later Bow River had to be

forded. We then went into camp and built huge fires, and everybody hung themselves up to dry.

The night of June 15th found us camped on the summit of the mountains at an elevation of five thousand three hundred feet. It was exactly three months from the date I left Salt Lake City to start on the journey. That night there was a snowfall of six inches.

Black bear were very numerous, several having been seen while on the trail and at wash, so we concluded on Fourth of July to invite two parties and have a grand bear hunt, to be followed by a dinner at my camp.

Huson's party all joined us except one who was coming to the dinner later. We formed a large circle beating the bush, and gradually drawing in toward the center expecting to have one or more bears, but we found none. In the meantime a bear walked into Huson's camp, helped himself to a basin of molasses, growled at the single unarmed occupant and departed.

At this time we were three hundred miles from the nearest postoffice, and had to send and receive all of our mail via Fort Benton, Montana. We had to maintain our own mail route for about two hundred miles.

The next winter the writer and four others made a trip from Fort Calgary to Moose Jaw, a distance of four hundred and fifty miles, without putting up a tent. In one place we had to carry our wood for six days. At the end of the sixth day we had only wood for one more fire and were twenty-five miles from the nearest timber. We went to bed supperless that night and saved our wood for breakfast. The next morning the thermometer was fifty-two degrees below zero. Fancy frying bacon and cooking slapjacks on the open prairie at that temperature.

We started on foot to make the twenty-five miles, telling the teamster to come as far as he could then unhook his horses and come on with them. About 4 p. m. those on foot reached the company's storehouse at Medicine Hat, and about six the teamster came in with three horses, one having given out. When we sent back for the wagon only his bones were found. The wolves had picked them clean. We were just a month making the trip from Fort Calgary to Winnipeg.

The next spring we crossed the summit going to the west side on the eleventh of May and had to shovel a path for our pack train through from two to four feet of snow for about two miles.

That season's work was very trying. For a long time we were working on the face of nearly perpendicular cliffs, at an elevation of from one hundred feet to three hundred feet above the river. The rock was a soft shale, and in places we could pick footholds so as to crawl around, in other places men were lowered over the face of the cliffs with ropes. For weeks we were working where a misstep would mean certain destruction, but we never had a man injured. Our pack trail, over which all of our

d to come was picked into the face of the mountains at an five hundred to six hundred feet above the river and was not nd a half wide. Our pack horses had been gradually accus- work so that they passed over it in perfect safety, but that hich had always worked on level ground in the valley of the iver, attempted to pass over it and became dizzy so they had dded and led. One horse went over the cliffs to the river

ntry was so very rough that in one part for a distance of three ld not find a place where we could set up our tents.

e from the summit to the Columbia River followed the Kick- River, which for most of the distance is very narrow, the ing right from the water to a height of from three thousand nd feet above the river. The slopes are covered with a dense mall pines and fir trees, while the surface is covered to a veral feet with a net work of the dried trunks of trees which illed by forest fires.

et we noticed fire on the mountains several miles below us, ral days it did not appear to make much headway. Finally anged and it began to come rapidly up the valley. At night ched a small creek which emptied into the river about d yards below our camp. At night the wind changed lown the canons, so that with the heavy dew we knew de until morning. The next morning we were up by light or the fire. We piled all our stores, bedding, etc., in the r camp ground and covered them with the tents which we soaked with water. We cleaned a space about fifteen feet ides and wet the ground. Then we set fire on all sides and rn the brush slowly outward from our clearing, but it soon got control, for within a few feet back of our camp the mountain as covered with timber as dry as tinder. When our fire it went up the slope as though it had been soaked with oil. time the fire crossed the creek below us and came up the had to go over the bank into the river for protection. In less inutes there was a mass of fire covering the mountains on both river clear to their summits and extending up the valley of e or six miles. The roar could have been heard for miles and s intense. For hours we had to sit close under the bank of the shallow water. It was not until nearly four o'clock in the at the heat and smoke had abated enough so we could raise up our tents for the night. All night long we could see the hear their roar and the crashing of falling timber further up where the fire was still raging. It was one of the grandest s man ever beheld and one never to be forgotten, but one

through which none of us would care to go again. Previous to this mountain goats and black bear had been very plentiful, but we did not see a trace of either again that fall.

On this work there was no doctor sent out and any cases of sickness or accident had to be attended to by the chief of the party who was expected to have flesh needles, silk and adhesive plaster for wounds and common remedies for sickness. Fortunately there was only one severe surgical case, though a number of minor cuts had to be sewed up There were no severe cases of sickness. The weather usually was good, the work interesting, though arduous, and all enjoyed it. We had some of the finest trout fishing in the world.

We will now shift the scene to a sub-tropical country.

In early December, 1887, the writer landed in Nicaraugua to take charge of a party on the surveys for a ship canal. The climate, method of living, means of transportation, and everything was new. The country where we were to work was an uninhabited wilderness, and the rain was falling in torrents. The work which I was to undertake was situated about twenty miles directly back from Greytown, but on the other side of a high range of hills. We spent two days in preparation and then took steamer up San Juan River forty miles to San Francisco Island where we were to have our base of supplies. We left Greytown at daylight with a heavy fog and mist, but the sun soon came out and we had a perfect day. Nothing could be more beautiful than the scenery along the river. Everything was new and interesting, the tropical vegetation, the alligators sunning themselves on the banks, the many colored parrots and macaws, the great iguanas (lizards five or six feet long), and monkeys jumping from limb to limb in the trees kept our attention fully occupied, and night came all too soon. We did not reach San Francisco Island until the next morning at daylight. From here our transportation was by means of steel canoes propelled by five or six men paddling. Each party had three canoes.

My route followed up a narrow tortuous stream with a strong current and filled with fallen timber. We had hardly entered the mouth ere the rain came and hardly let up for an hour for a whole month. At night we had to clear a small place and set up our tents to sleep in, while the cook was starting a fire with wet wood and cooking supper in a pouring rain. By the time a tent was up the soft wet ground would be a semi-liquid mud from six to ten inches deep. Our folding cots would barely reach above the mud and one had to stand on a box to dress and undress.

During the day everyone was in the water cutting logs out in places, in others hauling the boats over, and all the time the rain falling in torrents. When I say torrents I speak advisedly, for we recorded rainfalls of ten inches in twenty-four hours, thirty inches in six days, sixty-four inches in a month and three hundred inches in a year. Thus we toiled along for

...ssary week ere we reached a point where we could go no further ...r boats. We made a temporary camp and at once began prepara... a permanent camp about half a mile ahead beside a beautiful ...ll almost twenty feet in height. Here we had a natural bath tub ...out of solid rock about sixty feet long by ten feet in width with ...ight feet of water.

...took another week to clear off the camp site move our things and ...up. We flattered ourselves that we could at last take comfort. ...night we had a rainfall of nine inches between dark and daylight. ...et had mildewed and although we had a fly the water came through ...leave. We stretched rubber blankets over our beds and went to ... In the morning we found a sheet of water three inches deep all ...e bottom of the tent. That day we split logs and put in a floor. ...on learned to discard tents entirely and live in shacks thatched ...ed with palm leaves, with the sides entirely open. We usually ... a floor about a foot above the ground to allow air to circu... These were much dryer and every way more comfortable than

... Christmas day while in our temporary camp we ate dinner along... a large log, holding an umbrella in one hand and carving with the ... It was here one of our young men who was having his first ...once gave utterance to his feelings as follows: "I would start for ...tomorrow if the old man had not said if I came home he would take ...me his knee and paddle me." He was not the only one who felt ...ey.

...spite of the rain surveys had to be made. At first we tried to pro...ourselves by wearing ponchos, but in that warm climate they were ...uble and soon discarded. When we came in at night we would ...ur wet clothes out in the rain, take a bath and put on dry ones for ...ht. In the morning after breakfast we would wring the water out ...wet ones, pull them on and go to work.

...been working on the low grounds in the swamps the men would be ...er all day long, the axmen and chainmen frequently having to ...but in spite of all this all were healthy and usually kept in good

...underbrush in the woods is so exceedingly dense that one man might ...within ten feet of another and never see him. It was absolutely ...uible to sketch topographically at all, everything had to be done by ...ments. The work was necessarily slow and expensive.

...uch more might be said about this class of work but this paper is ... over long. If these reminiscences have brought home to the mind ...young engineer the necessity of a thorough knowledge of things ...than technical and impressed the fact that an engineer's road to ... is frequently not a path of roses, the writer's end is accomplished.

# THE FOUNDATION OF OUR KNOWLEDGE OF HYDRAULIC CURVE RESISTANCE.

GARDNER S. WILLIAMS, '89.

It is well that we understand the basis upon which the everyday formulæ of science are established in any case, and it is particularly so where the formulæ are of the empiric class, for as is being more generally recognized now than formerly, it is a questionable proceeding to apply an empiric formula to cases much beyond the limits of the experiments upon which it is founded. The science of hydraulics, as we know it, is a little more than a century old, but its working formulæ are almost entirely empiric and many of them have been but slightly improved since they were first proposed.

The subject of the resistance to the flow of water in pipes due to curvature had received nearly all of its experimentation and study previous to 1855 and since that time, if we except a brief series of experiments made in connection with another investigation in 1888, there has been no addition to our knowledge of it.

The recorded experiments upon curvature in pipes may be divided into two classes: Those on sinuous pipes and those on pipes with single bends. The earlier experiments, perhaps, for want of sufficiently delicate means of measuring losses of head, experimented mainly upon the former and for want of a proper understanding of the effect of the single curve in connection with subsequent ones their deductions have been sometimes erroneous and usually of little practical significance to the ordinary enquirer who lays his pipe as straight as possible and seldom introduces more than a single right angle at a time.

The first experimenter to investigate curves appears to have been Bossut whose first work "Nouvelles Experiences sur la resistance des fluides," was published in 1777, and his "Traite theoretique et experimental d'Hydrodynamique" in 1786. According to D'Aubuisson who has abstracted Bossut's experiments, he used a pipe 0.088587 feet in diameter and 53.2834 feet long, and when extended horizontally in a straight line found it to deliver 0.736 cubic feet per minute under a head of 1.0662 feet; then bending it into a serpentine form of six well rounded curves, the delivery was, all else being as before, 0.720 cubic feet per minute. (D'Aubuisson, Bennett's Translation, page 213).

The next experimenter to deal with curvature was Dubuat, who published his "Principes Hydraulique" in 1786, a second edition appearing in 1816. Dubuat records a description of twenty-five experiments upon curved pipes of which twenty-two were upon pipe 0.0888 feet in diameter and the other three upon one 0.1776 feet in diameter. Eleven of these

riments are quoted by D'Aubuisson (Bennett's Translation, page and the whole series is tabulated by Dr. Thomas Young ("Philo- ical Transactions Royal Society 1808," page 174) who there deduces them two formulæ. These experiments as published by Dr. Young, reduced to English measures are as follows:

TABLE I.

*Dubuat's Experiments upon Curves.*

| d. Diameter of Pipe. | θ. Central Angle of Curve. | R. Radius of Curvature. | V. Velocity per Second. | h. Loss of Head. | L. Length of Pipe as Given by D'Aubuisson |
|---|---|---|---|---|---|
| Feet. | | Feet. | Feet. | Feet. | Feet. |
| 0.088 | 288° | 0.295 | 10.89 | 0.422 | |
| 0.080 | 288° | 0.296 | 9.45 | 0.311 | |
| 0.080 | 288° | 0.296 | 7.55 | 0.207 | |
| 0.080 | 288° | 0.296 | 5.26 | 0.096 | |
| 0.083 | 216° | 0.296 | 7.54 | 0.321 | 10.391 |
| 0.083 | 144° | 0.296 | 7.54 | 0.119 | 10.391 |
| 0.083 | 72° | 0.296 | 7.54 | 0.067 | 10.391 |
| 0.083 | 191.5° | 0.5455 | 5.16 | 0.067 | |
| 0.080 | 186.5° | 0.5455 | 7.54 | 0.154 | 10.391 |
| 0.080 | 147.4° | 0.5455 | 7.54 | 0.0905 | |
| 0.083 | 98.6° | 0.5455 | 7.54 | 0.067 | |
| 0.080 | 49.1° | 0.5455 | 7.54 | 0.033 | |
| 0.080 | 36° | 0.04707 | 7.54 | 0.524 | |
| 0.080 | 112.5° | 0.04707 | 5.54 | 0.353 | |
| 0.080 | 112.5° | 0.04707 | 5.16 | 0.163 | |
| 0.080 | 288° | 0.284 | 5.16 | 0.133 | 12.300 |
| 0.080 | 144° | 0.296 | 5.16 | 0.067 | |
| 0.080 | 72° | 0.296 | 5.16 | 0.033 | |
| 0.083 | 720° | 0.246 | 6.36 | 0.524 | 10.391 |
| 0.083 | 288° | 0.246 | 5.22 | 0.146 | |
| 0.080 | 288° | 0.296 | 2.69 | 0.038 | 12.300 |
| 0.080 | 288° | 0.289 | 2.50 | 0.035 | 65.456 |
| 0.0778 | 288° | 0.284 | 5.29 | 0.119 | 22.671 |
| 0.0778 | 288° | 0.284 | 7.66 | 0.258 | 22.671 |
| 0.0778 | 284.8° | 0.8792 | 7.66 | 0.767 | 22.671 |
| | 288° | 0.284 | | | |
| | 112.5° | 0.957 | | | |

Not having access to Dubuat's own account of his work the writer only add to the information in this table the statement of D'Aubuis- that Dubuat first took the straight pipes and ascertained the discharge a given time under a certain head, and then, having bent them, ved the head required to discharge through them the same quantity ater in the same time, the difference of the two heads giving him the stance due to the curves. From these experiments Dubuat deduced a ula for curve resistance, which is based upon the assumption that central filament of the water approaching a curve continues in a ght line in the prolongation of the axis of the straight pipe until it is

deflected by contact with the outer wall of the curve, when it is assumed to make an angle $\Phi$ of reflection with the tangent to the curve at that point and continue in this new direction until again similarly deflected. This formula for English measures is $h=.00375V^2\Sigma\sin^2\Phi$. It was applied to but fifteen of the foregoing experiments by its author who rejected the remaining ten as irregular because, according to Dr. Young, they did not agree with his equation. From these experiments Dr. Young deduced his equation, $h=\frac{.000006\Theta R^{\frac{1}{2}}V^2}{R}$, R being the radius of curvature and V the velocity, which fits all four of the experiments very well; and Navier deduced also from them $h=(.01279551+1.0186R)\frac{l'}{R^2}\cdot\frac{V^2}{2g}$, where $l'$ is the length of the curve measured along the convex side of the stream.

The next experiments upon curves appear to have been made by Venturi, and published in 1797. He made three pipes, according to D'Aubuisson, 15 inches long and 1.3 inches in diameter. One was straight, the second had a curve of 90° gently rounded and the third had an abrupt angle of 90°. Under a head of 2.887 feet they filled a vessel containing 4.838 cubic feet in 45, 50 and 70 seconds respectively.

In 1831 George Rennie published in the Philosophical Transactions the results of a series of experiments upon a lead pipe ½ inch in diameter and fifteen feet long, which was very carefully drawn over a mandril. The curves used were of 3¼ and 7½ inches radius, and his first experiment embraced one 3¼-inch curve of 90° to the right, joining one 7½-inch of 180° to the left, which latter joined one 3¼-inch of 90° to the right, and this appears to have been followed by a short tangent. The pipe was first experimented upon while straight, the end being fixed in a wooden plug which fitted an orifice in the side of the reservoir. Rennie records his experiments as follows:

TABLE II.

*Rennie's Experiments upon Elbows and Curves.*

*I. Pipe Bent as Above Described.*

| Constant Height of Surface of Water Above Center of Orifice. | Time to Discharge One Cubic Foot by Bent Pipe. | Time to Discharge One Cubic Foot by Straight Pipe. | Remarks. |
|---|---|---|---|
| 4 feet. | 147 Seconds. | 143 Seconds. | The position of the bends, whether vertical or horizontal, at either extremity of the pipe, does not affect the result. |
| 3 feet. | 175 Seconds. | 164 Seconds. | |
| 2 feet. | 213 Seconds. | 208 Seconds. | |
| 1 foot. | 316 Seconds. | 312 Seconds. | |

*Pipe Fifteen Feet Long, Half-inch Bore, with Fourteen, Seven and a Half Inches Radius Semicircular Bends, Beginning and Terminated with a Quarter Circle Bend of Three and a Fourth Inches Radius. Serpentine.*

| Head: Height of Surface of Water above Centre of Orifice. | Time to Discharge One Cubic Foot by Bent Pipe. | Time to Discharge One Cubic Foot by Straight Pipe. | Remarks. |
|---|---|---|---|
| 4 feet. | 162 Seconds. | 141 Seconds. | The expenditure is diminished by the bends from one-fifth to one-third, which represents the friction in the pipe. |
| 3 feet. | 200 Seconds. | 164 Seconds. | |
| 2 feet. | 247 Seconds. | 208 Seconds. | |
| 1 foot. | 321 Seconds. | 312 Seconds. | |

In Case I as compared with a straight pipe the resistance varies from 1-36 to part of that the straight pipe.
In Case II the resistance varies from 1-19 to 1-39 of the resistance of the straight

The increased number of bends does not increase the resistance in the ratio of number of bends but merely shows an increased resistance.

*Pipe Fifteen Feet Long, Half-inch Bore, Bent in Right Angled Elbows.*

| Head. | For One Right Angle, Eight and One-Half Inches from End of Pipe. | For Twenty-four Right Angles, 6¾ Inches Apart. Serpentine. | Remarks. |
|---|---|---|---|
| 4 feet. | 180 Seconds. | 305 Seconds. | |
| 3 feet. | 234 Seconds. | 405 Seconds. | |
| 2 feet. | 296 Seconds. | 504 Seconds. | |
| 1 foot. | 371 Seconds. | 672 Seconds. | |

Comparing the expenditure for one right angle with that for twenty-four the resistance is only in the ratio of about one to two.

Rennie then calls attention to the incorrectness of both Dubuat's and Eytelwein's formulæ but wisely refrains from deducing one of his own.

We now come to the investigations of Dr. Julius Weisbach which were published from 1845 to 1853, and from which, with some of Dubuat's, that authority deduced his well known and generally accepted formula for curve resistance: $h = \left\{0.131 + 1.847\left(\frac{r}{R}\right)^{\frac{7}{2}}\right\} \frac{V^2}{2g} \frac{\theta}{180^\circ}$. As this formula is the one quoted by the principal authorities of England, Germany, Italy and America—though the French patriotically refuse to recognize it—the experiments upon which it is based should be especially interesting. Its author after entering upon a theoretical discussion of the laws of curve resistance, suddenly drops the subject and introduces this formula which he states is purely empirical.

Before taking up his experiments upon curves Weisbach experimented with a series of mouthpieces and pipe connected in sections to his res-

ervoir and determined the discharge for a given time. The head was measured by hook and point gauges and the quantity discharged was determined by measurement in a small tank whose dimensions were very carefully determined. It does not appear that he used weights to determine the quantity of water discharged. The rise of water in the measuring tank was read by a combination of a hook and point gauge, the former being set at the level of the water surface at the beginning of the experiment and the surface at the close being located by the latter. They were carried on a single spindle, the zero of the scale being at the point of the hook gauge. From these experiments he established the coefficients of discharge for the various pieces, alone and in combination, his results taking the form $Q=\mu F\sqrt{2gh}$ where Q is the discharge, F the area of cross section and $\mu$ the coefficient of efflux. He also deduces the coefficient of resistance $\xi$ which is the ratio of the loss of head $h_f$ to the velocity head $\frac{V^2}{2g}$. The relations between these coefficients are as follows:

If V is the actual velocity of efflux then $\frac{V}{\mu}$ is the theoretical velocity, i. e. that due to the head $h$, and we have $\frac{V^2}{\mu^2}=2gh$ or $h=\frac{V^2}{2g\mu^2}$. If $h_f$ = the head lost by the frictional resistances, that is the head to which the theoretical velocity is due less that to which the actual velocity is due,

$$h_f=\frac{V^2}{2g\mu^2}-\frac{V^2}{2g}=\left(\frac{1}{\mu^2}-1\right)\frac{V^2}{2g}, \text{ and since } \xi=\frac{h_f}{\frac{V^2}{2g}} \text{ we have:}$$

$$\xi=\left(\frac{1}{\mu^2}-1\right) \text{ and } \mu=\frac{1}{\sqrt{1+\xi}}$$

For Weisbach's theoretical discussion of curve and bend resistance the reader is referred to Coxe's Translation of Volume I of the "Mechanics of Engineering," and though it is also given in "Die Experimental Hydraulik" we pass on to a consideration of his published experiments.

The mouth piece A used in the following experiments was of brass 1 cm. in internal diameter and 3 cm. long, and was rounded at the entry end and attached to a plate that was screwed into the side of the reservoir from which the water was obtained. The piece B was of the same diameter and material but its length is not given. From the plates it appears to have been about 5.5 diameters in length. The coefficients of efflux and resistance for these two pieces were previously determined and are then subtracted from those for the whole appartus to get those for the elbows and curves.

The method of experimentation was to observe the time required to deliver a certain quantity of water through the apparatus being examined, starting with the water at a given height. By this means the only observed quantity difficult to determine was the time and any apparent errors are probably to be found in it.

## TABLE III.

*...k's Experiments upon Elbows and Curves as Published in Die Experimental Hydraulik.*

| Number part of Experiment | Description | Mean Head h Meter | Time of Efflux t sec. | Coefficient of Efflux $\mu_1$ | Coefficients of Resistance: For Whole Apparatus $\frac{2gf}{\mu^2 v^2} = \zeta_1$ | Mean for W. ular Apparatus $\zeta_2$ | For Additional Apparatus $\zeta_3$ | For Part Investigated $\frac{\zeta_1 - \zeta_2}{l} =$ |
|---|---|---|---|---|---|---|---|---|
| Elbow | Right-angled brass elbow 1 cm., through all such leg on the first time [illegible] | 0.1472 | 202. | 0.624 | 4.417 | | | |
| do. | [illegible] | 0.0891 | 121. | 0.64 | 2.140 | 2.191 | 0.199 | 1.944 |
| do. | [illegible] | 0.1060 | 78 | 0.781 | 1.849 | | | |
| do. | The same as No. 1, connected by pipe B | 0.0874 | 9.45 | 0.5 | 2.451 | | | |
| do. | | 0.2000 | 134. | 0.629 | 1.791 | | | |
| Two Elbows | | 0.0850 | 77. | 0.591 | 1.165 | 1.300 | 0.403 | 1.870 |
| Two Elbows | The same as No. 2 with a second elbow similar to the first attached at end of B, turning stream in the same direction. | | | | | | | |
| do. | | 0.1976 | 145.5 | 0.459 | 3.349 | | 0.324 | 5.225 |
| do. | The same as 2a with second elbow reversed 180° | 0.2004 | 149. | 0.459 | 3.770 | | | |
| do. | | 0.0850 | 97. | 0.488 | 3.247 | | | |
| do. | The same as 2b with elbows adjacent and pointing in opposite directions. Pipe B at end | | | | | 3.402 | 0.760 | 5.842 |
| do. | | 0.1998 | 148.5 | 0.459 | 3.748 | | | |
| do. | | 0.1982 | 97.5 | 0.467 | 3.581 | | | |
| do. | The same as 2c with pipe B removed | 0.1994 | 147. | 0.464 | 3.668 | | | |
| | | 0.0969 | 96.5 | 0.464 | 3.818 | 3.402 | 0.332 | 5.919 |
| Curve 90° | Brass, diam. 1 cm., radius 1 cm., connected to manifold A | 0.2008 | 85.55 | 0.459 | 3.486 | | | |
| do. | | 0.1990 | 86.75 | 0.448 | 4.042 | 3.486 | 0.180 | 5.324 |
| do. | The same as No. 4 with pipe B at outlet | 0.2046 | 89.25 | 0.744 | 4.711 | | | |
| do. | | 0.1991 | 94. | 0.744 | 4.438 | 3.809 | 0.280 | 5.229 |
| do. 180° | Brass, diam. 1 cm., radius 1 cm., so united to manifold A | 0.2006 | 8.625 | 0.773 | 1.469 | | | |
| | | 0.4000 | 17.25 | 0.795 | 0.384 | 0.926 | 0.346 | 0.440 |
| Two Curves | A second similar 180° curve was connected to the apparatus as in No. 6 and united so as to reverse the direction of flow (from $\zeta_2$ it appears that B was also included) | 0.2000 | 90.75 | 1.004 | 1.139 | | 0.304 | 0.548 |
| Three Curves | To the combination of No. 7 this 90° curve of No. 4 was added, and turned so as to reverse the direction of flow | 0.2000 | 112.5 | 0.806 | 1.719 | | 0.324 | 1.350 |
| Two Curves | The combination of No. 4 was extended by the 180° curve and the pipe B, direction of flow being reversed | 0.2000 | 67.25 | 0.629 | 1.161 | | 0.257 | 0.928 |
| do. | The same as No. 9 with pipe B removed | 0.2000 | 66. | 0.660 | 1.105 | | 0.149 | 0.867 |
| Three Curves | To the combination of No. 10 a second curve of 90° was added and turned to again reverse the direction of flow | 0.2000 | 71.25 | 0.632 | 1.393 | | 0.149 | 1.445 |

NOTES ON ABOVE EXPERIMENTS. TABLE III.

**Experiment No. 1.**—Weisbach explains the high value of $\xi$ by the fact that the stream having been contracted in passing around the elbow escapes into the air before the head used in this contraction is regained.

**Experiment No. 2.**—Weisbach here states that as the coefficient $\xi$ is greater than that obtained from the Table in "Mechanics" which was deduced from a number of elbows of larger diameter, he concludes the resistance due to elbows in a small pipe will be greater than that in a larger one for the same angular deflection. Though it is possible that this view may be the correct one it is interesting to enquire what might have been the effect if the pipe B had been longer, for if adding $5\frac{1}{2}$ diameters to the length of a leg already two diameters long has the effect of reducing $\xi$ from 1.902 to 1.636 it seems a bold assumption that no further reduction would occur.

**Experiment No. 3.**—From this the value of $\xi$ for two elbows is 3.302 and by No. 2 it was found for one elbow to be 1.636. If, however, we take the value from No. 2 for the same heads as in No. 3 we get $1.996 - .290 = 1.706$. It appears, therefore, that the resistance due to the second curve is less than that due to the first. This conclusion, although frequently drawn from these experiments may be somewhat misleading. Weisbach divides the coefficient 3.302 by two getting 16.51 for the resistance of each bend which he considers in good accord with No. 2. The high value of $\xi$ for No. 3 is explained as in No. 1.

**Experiments Nos. 4 and 5.**—The value of $\xi$ is higher than that given by the tables referred to under No. 2.

**Experiment No. 6.**—The outflowing stream diverged like a cone. Weisbach says: "Since the coefficient of friction may be taken as .075 there remains only $\xi = 0.460 - .075 = 0.385$, whence it appears that the resistance of the semicircle is but little greater than that of the quadrant."

**Experiment No. 7.**—The coefficient for the two curves being 0.808, if that of each were the same they would be 0.404 but from No. 6 $\xi_0 = 0.460 + 0.324 = 0.784$ and $\xi$ for one curve $= 1.138 - 0.784 = 0.354$. (Wiesbach gives $1.138 - 0.764 = 0.353$ which is apparently an error as these values do not agree with No. 6).

**Experiment No. 8.**—Subtracting $\xi_1 = 1.138$ for No. 7 we have for the 90° curve alone $\xi = 1.719 - 1.138 = 0.581$, this high value being due to the reversal of the stream by this curve.

**Experiment No. 9.**—Subtracting from $\xi_1$ the value of $\xi_1$ in No. 5 we have $\xi$ for the semicircle $= 1.185 - 0.626 = 0.559$ which Weisbach considers in good accord with with the value 0.460 in No. 6.

**Experiment No. 10.**—Subtracting from $\xi_1$ the value of $\xi_1$ in No. 4 we have $\xi$ for the semicircle $= 1.105 - 0.502 = 0.603$.

**Experiment No. 11.**—Subtracting the coefficient for the combination in No. 10 there remains for the last curve of 90° $\xi = 1.593 - 1.105 = 0.488$.

ng a single 90° elbow, a single 90° curve and a single 180° curve of
e list, successively in combination with a long pipe, each curve
minated by the pipe B the axes being in each case horizontal
h obtained the following values of the cofficient $\ell$: For the elbow,
d 1.661; for the 90° curve, 0.517 and for the 180° curve practically
e value as for the 90° curve.

m all of the foregoing it must be apparent that the position of the
the system, whether in straight pipe or in combination with
rves, has a considerable bearing upon the coefficient of resistance.
the foregoing experiments which were made in the laboratory, on
of the small capacity of the reservoir the head continually varied,
r a considerable range in each experiment. In the summer of
isbach made further experiments out of doors under high heads
the supply of water was taken from a large pipe 18½ inches
) diameter. This insured a fairly constant head. The experi-
re recorded in "Der Civil Ingenieur," 1863. The pipe approach-
rifice to which the apparatus experimented upon was attached,
reased in diameter to reduce the velocity of approach so that the
of a 1 cm. diameter would be 441 times that of approach. The
e measured by a mercury column, corrections being made for
ity and temperature. The water was measured in a tank as before
time of discharging a given quantity under a given head was
d.

cluding, Weisbach says: "From this investigation we find that
stance of water flowing through elbows is much greater than
curves, though the conformity of results with one another and
se of another investigation (Experimental Hydraulik) leaves
be desired. It is also apparent that the resistance in elbows for
e velocity is greater for small than for large pipe."—See Table IV.
"Der Civil Ingenieur," Vol. X., Weisbach publishes another
f experiments upon curves and elbows, this one being with low
—See Table V.

## TABLE IV.

*Weisbach's Experiments on Elbows and Curves as Published in Der Civil Ingenieur, Vol. IX., 1863.*

| No of Experiment. | Subject of Experiment. | DESCRIPTION. | Head. $h$ Meter. | Time. $t$ Seconds. | Volume. V Cub. Met. | Coefficient of Resistance. For Whole Apparatus. $\xi_1$ | For Auxiliary Apparatus. $\xi_0$ | For Part Investigated. $\xi$ |
|---|---|---|---|---|---|---|---|---|
| 12 | Elbow | Right angled, brass, diam 1 cm., length of each leg on center line 3 cm., connected to a brass mouth-piece 1 cm diam. and 5 cm long with inlet rounded, and terminated by a discharge pipe 1 cm. diam and 5 cm. long | 16.971 | 180 | 0.14806 | 2.1842 | 0.2245 | 1.9 97 |
| 13 | do. | Right angled, brass, diam. 1.4 cm, length of each leg on center line 4 cm., connected to a brass mouth-piece 1.402 cm. diam. and 5 cm long with inlet rounded, and terminated by a discharge pipe 1.400 cm. diam. and 1 cm. long | 17.092 | 120 | 0.22015 | 1.3746 | 0.1788 | 1.1958 |
| 14 | do. | Right angled, brass diam. 2.44 cm., length of each leg on center line 4 cm., connected to end of zinc tube 2.44 cm. diam. and 10.21 met. long, which was attached to a rounded entry mouth-piece 2.441 cm. diameter. | 16.896 | 120 | 0.32010 | 8.8278 | 7.5215 | 1.3063 |
| 15 | Curve | 90°, brass, diam. 1 cm., radius 1 cm., connected to entry and disch'rge pieces of No. 12 | 16.970 | 180 | 0.21433 | 0.5195 | 0.2245 | 0.2950 |
| 16 | do. | 90°, brass, diam. 1.4 cm., radius 1.4 cm., connected to entry and discharge pieces of No. 13 | 17.081 | 120 | 0.2 919 | 0.8084 | 0.1788 | 0.6296 |
| 17 | do. | 90°, brass, 2.44 cm., radius 1.22 cm., connected to zinc tube and mouth-piece of No. 14 | 16.1841 | 120 | 0.34332 | 7.8408 | 7.5215 | 0.3193 |

TABLE V.

*...ch's Experiments on Elbows and Curves as Published in Der Civil Ingenieur, Volume X., 1864.*

| Number of Experiment. | DESCRIPTION. | Head $h$ Centimeter. | Time $t$ Seconds. | Volume $V$ Cubic Centimeters. | Coefficient of resistance. For Whole Apparatus. $\zeta_1$ | For Auxiliary Apparatus. $\zeta_0$ | For Part Investigated. $\zeta$ |
|---|---|---|---|---|---|---|---|
| Elbow | Right angled, brass, diam. 1.402 cm., length of each leg on center line, 7 cm., connected to brass mouth-piece of same diam., with rounded entry, 5 cm. long, and to efflux pipe of same diam., 5 cm. long. Velocities, 0.5196 and 0.2885 m. | 2.2175<br>1.9056 | 120<br>120 | 3650.153<br>2792.637 | 3.32976<br>3.44780 | 0.91626<br>0.81626 | 2.5137<br>2.6315 |
| Curve | 90°, brass, diam. 1.402 cm., R=d, connected to same pieces as elbow in No. 19. Velocities, 0.5196 and 0.3681 m. | 2.1701<br>1.7774 | 140<br>120 | 4090.160<br>3502.265 | 1.26970<br>1.56469 | 0.91626<br>0.81626 | 0.3657<br>0.7444 |
| Two Curves | 90° and 180°, brass, diam. 1.402 cm., R=d, connected to same pieces as in No. 19, and separated by pipe of same diameter 5 cm. long, the 180° curve being nearer to discharge. Velocities 0.5196 and 0.3654 m. | 2.1828<br>1.7459 | 150<br>150 | 3364.200<br>3419.959 | 2.93450<br>2.84063 | 0.90252<br>0.80952 | 2.0925<br>2.3786 |
| Elbow | Right angled, brass diam. 1.402 connected to brass mouth-piece and discharge tube of same diam., each 15 cm. long. Velocities 0.5290 and 0.3525 m. | 2.1994<br>1.9017 | 60<br>60 | 3047.703<br>2601.978 | 2.90073<br>3.04311 | 0.72584<br>0.72584 | 2.1749<br>2.3173 |
| Curve | 90°, brass, diam. 1.402 cm., R=d, connected like elbow of No. 21. Velocities 0.4294 and 0.3656 m. | 2.1284<br>1.7288 | 60<br>60 | 2903.977<br>2368.356 | 1.93974<br>1.56900 | 0.72584<br>0.72584 | 0.6024<br>0.7602 |
| Curve | 90°, brass, diam. 2.445 cm., R=d, connected to end of a zinc tube 311 cm. long and 2.4780 cm. diameter. Velocity 0.3259 m. | 0.3259 | 120 | 1017.4.200 | 7.20437 | 0.94755 | 0.2660 |
| Curve | 180°, brass, diam. 2.445 cm., R=d, connected like 90° curve of No. 23. Velocity, 0.3268 m. | 0.7958 | 120 | 1411.023 | 7.51689 | 0.94755 | 0.6734 |
| Curve | Right angled, diam. 2.445 cm., connected like curves of Nos. 23 and 24. Velocity 0.3261 m. | 2.4010 | 120 | 1071.100 | 6.49014 | 0.94755 | 1.4998 |

Commenting upon these experiments, Weisbach says: "We see from the above experiments that the coefficient of resistance for an elbow, even at low velocities, is much greater than that of a curve, when the stream is in both cases turned ninety degrees. It also appears from this investigation that the resistance due to change of direction decreases as the diameter of the pipe increases. The mean results for a right angle elbow are:

Exp. No. 18, d = 1.0 cm. $\xi = 2.57$ h = 0.02058.
" " 21, d = 1.4 " $\xi = 2.28$ h = 0.02051.
" " 25, d = 2.45 " $\xi = 1.46$ h = 0.02491.
" " 1, d = 1.0 " $\xi = 2.22$ h = 0.087.
" " 1, d = 1.0 " $\xi = 1.94$ h = 0.899 and as stated in Mechanics of Engineering for elbows of greater diameter, $\xi = 0.984$.

For curve Exp. No. 22, d = 1.2 cm. $\xi = 0.681$ h = 0.01934.
" " 23, d = 2.445 " $\xi = 0.2608$ h = 0.02326.
" " 4, d = 1.0 " $\xi = 0.324$ h = 0.400.
" " 5, d = 1.0 " $\xi = 0.378$ h = 0.899 and as stated in Mechanics of Engineering the value for curves of greater diameter is $\xi = 0.294$.

The experiments upon elbows and curves of larger diameter to which Weisbach refers and from which he deduced his formula and tables as published in his "Mechanics of Engineering," have apparently never been printed, and so far as the writer has been able to learn there is no data concerning them available. From the fact that in none of his later series of experiments did he use anything of a diameter greater than 2.5 centimeters, about one inch, and that he also used in the production of his formula some of Dubuat's results, none of which were upon pipe more than 2.2 inches in diameter, it is safe to say that the formula which the writers of text-books would have us apply to pipes from six inches to six feet in diameter has been derived from experiments upon tubes whose average diameters have not been above one inch.

Even for the diameters which these experiments cover, and granting to them a very high degree of accuracy, which they undoubtedly deserve, they seem hardly comprehensive enough to base a formula upon, and there is little reason to think that the unpublished series of investigations were conducted in a very different manner or afforded very different results from those presented above. In all of these the method of determining the coefficient for the curves seems open to question, and the lack of sufficient length in the discharge pipe, and in many cases, its entire absence, introduce conditions not likely to be found in practice.

In addition to the foregoing experiments Dupuit "Conduite et Distribution des Eaux," states that in pipe up to 8 cm. diameter he has never found a 90° curve to show a resistance greater than that due to two meters

of pipe; and Hagen "Wasserbau" says that a pipe 0.384 inches in diameter and 8 feet long delivered the same quantity of water under the same conditions of time and head when bent into a circle as when straight, and while giving a reduced discharge when bent more sharply, but in the latter case its cross section reduced by a change from the circular to the elliptical form due to bending.

In the minutes of Proceedings of the Institute of Civil Engineers, Vol. XII, there is an account of a series of experiments upon curves in lead pipe of $\frac{3}{8}$, $\frac{1}{2}$, $\frac{3}{4}$, and 1 inch diameter, made in Liverpool. The radius of curvature of the bends is not given and the only interesting thing about the series is the contradiction of Rennie's statement that the discharge is the same whether the bend is near the inlet or near the efflux end, these experiments showing the discharge to be greater when the curves are near the inlet end.

The next, and to date, so far as the writer is aware*, the last published experiments upon curves were those of Mr. John R. Freeman, made at Lowell in 1888 and published in his classic memoir on "The Hydraulics of Fire Streams," in the Transactions of American Society of Civil Engineers, Vol. XXI.

The results of this last investigation are, in the light of what has gone before, or at least in that of the commonly accepted theories, somewhat startling. In brief they are as follows:

| | |
|---|---|
| Flow straight at beginning of experiment, 2½ inches in diameter, length 51.8 feet, 17.0 feet per second velocity, loss of head | 8.35 lbs. |
| Flow straight at end of experiment, 2½ inches in diameter, length 51.8 feet, 17.0 feet per second velocity, loss of head | 8.55 lbs. |
| Flow bent around 4 curves of 90°, with 2 feet radius, length 51.8 feet, 17.0 feet per second velocity, loss of head | 9.04 lbs. |
| Flow bent around 4 curves of 90°, with 3 feet radius, length 51.8 feet, 17.0 feet per second velocity, loss of head | 9.28 lbs. |
| Flow bent around 4 curves of 90°, with 4 feet radius, length 51.8 feet, 17.0 feet per second velocity, loss of head | 9.32 lbs. |

From this it is seen that the sharper the curves, the less the resistance, while the ordinary theory, and common judgment would indicate the reverse, but from the foregoing experiments of the older experimenters it is at once seen that none of them approached the conditions of Mr. Freeman's investigation and however much we might be inclined to doubt his results we must bear in mind that there is nothing in the work of his predecessors which can be made to contradict them. Although Mr. Freeman's experiments have now been in print nearly ten years, the latest of our hydraulic text-books are still blindly quoting Weisbach, or else maintaining that curve resistance is insignificant, and can be almost wholly eliminated by increasing the radius of the curves.

*The beginning of an investigation of curvature in small pipe is given by H. T. Bovey and T. F. Strickland in the Transactions of the Royal Society of Canada for 1894, but the results so far are not of sufficient value to be included here, although they give promise of much in the future.—G. S. W.

## WHAT IS THE TEMPERATURE OF MAXIMUM DRAUGHT IN A CHIMNEY?

ROBERT C. STEVENS, '95.

It is interesting to note how the statement of an apparent fact, once asserted by an authority, and oft-quoted and relied upon by succeeding writers, may be accepted and reiterated long after its falsity has been repeatedly demonstrated.

The theory that a maximum draught, or the delivery of a maximum weight of gases, occurs in a chimney at a temperature of about 600° Fahrenheit, has been advanced and debated for many years and very generally accepted. It was first proposed by Peclet in his earlier works and was adopted by as eminent an authority as Professor Rankine; but it is a significant fact that Peclet, in the later editions of his works, abandoned this theory for a new one that does not give a maximum. However, although the author of the theory admitted its error and recent experiment and observation disproves it, the statement of a maximum draught at 600° Fahrenheit still appears in many a text-book accompanied by its mathematical demonstration. Such being the case, there is sufficient reason for calling attention to the subject at this time.

As a mathematical discussion the demonstration is simple and interesting. That its conclusion is in error, due to a false assumption, may be more clearly understood after a review of the problem. The following is in brief the usual form of its statement:

"According to Peclet," (He is always quoted, though the change of opinion that he experienced in later years is rarely mentioned.) the height of head necessary to produce a given velocity in a chimney, is—

$$h = \frac{u^2}{2g}\left(1 + G + \frac{fl}{m}\right)$$

Where

h = head necessary to produce velocity (u) expressed in feet of column of hot gases.
u = issuing velocity of hot gases, in feet per second.
g = acceleration due to gravity = 32.2.
G = co-efficient of resistance of grate and fuel bed to the entrance of air.
f = co-efficient of friction of sides of flue and chimney, which depends for its value upon the condition of the surfaces.
l = total distance, in feet, traversed by gases to top of chimney.
m = area of section of chimney divided by its circumference.

Then in the above equation, the first term is the resistance due to acceleration and the second and third the frictional resistances in furnace and flue respectively. Peclet "estimated" f = 0.012, though experiment

uld indicate that value to be somewhat too low. He also "asserted" h, with ordinary grates burning from 20 to 24 pounds of coal per square t per hour, G = 12. If these substitutions are made and the above ula solved for v, we have:

$$v = \sqrt{\frac{2\,gh}{13 + \frac{0.012\,l}{m}}}$$

Now h may be expressed in terms of the height of the chimney:

$$h = H\left(0.96\,\frac{t_1}{t_2} - 1\right)$$

Where

l = height, in feet, of chimney above grates.
= mean absolute temperature of gases in chimney.
= absolute temperature of external air.

Substituting, the second equation becomes:

$$v = \sqrt{\frac{2\,g\,H}{13 + \frac{0.012\,l}{m}}}\sqrt{0.96\frac{t_1}{t_2} - 1}$$

Then the weight of hot gases discharged per second is:

$$w.\,A\,v = \frac{t_2}{t_1}\left(0.0807 + \frac{1}{V_0}\right) A \sqrt{\frac{2\,g\,H}{13 + \frac{0.012\,l}{m}}}\sqrt{0.96\frac{t_1}{t_2} - 1}$$

$$= (\text{constant})\sqrt{\frac{0.96\frac{t_1}{t_2} - 1}{t_1}}$$

Where

= weight of a cubic foot of gases at temperature $t_1$.
= absolute temperature at 32° Fahrenheit.
= volume, in cubic feet, of air at 32° Fahrenheit, supplied per pound of fuel burned.
= area of cross-section of chimney flue in square feet.

The above will be a maximum for $t_1 = 2\frac{1}{2}\,t_2$, or the best chimney weight takes place when the absolute temperature of the gases in the himney is to that of the external air as 25 to 12, or when the temperature the flue gases is in the neighborhood of 600° Fahrenheit. For example: hen the external air is at 50° Fahrenheit the temperature of maximum eight is 604° Fahrenheit. When this condition is fulfilled, the preceding uation gives h = H and the density of the hot gases is one-half that of e external air.

Now it appears reasonable that in a chimney of given dimensions, the ad and the velocity and consequently the quantity of gases discharged, the "flow of weight," increases with the internal temperature. But it

does not do so to an unlimited extent; for, while the draught power is increasing as the result of higher temperature, the air in the chimney is expanding and there comes a point where the decrease in density due to this increase in volume counterbalances the increase in velocity. Beyond this point there is a diminution in the weight of the discharge. This limit of gas delivery also determines the amount of fuel that can be burned on the grate. Now, if 600° is the point of maximum draught and is even slightly exceeded in practice, the delivery of hot gases and the corresponding supply of air to the fuel would decrease, with a resultant diminution in fuel consumption, followed by a consequent reduction of stack temperature. Not only then is 600° the temperature of maximum draught, but the maximum temperature attainable with natural draught; a conclusion which is manifestly absurd and that will be contradicted by anyone who has observed the operation of steam boilers. This temperature is often exceeded, 650°, 700°, even 850° being not uncommon; though no one would defend such cases as representative of good practice.

Where then is the mathematical discussion incorrect? Merely in its assumption that the value of G, or coefficient of resistance of grate and fuel bed, is a constant. Experiment has shown and on deliberation reason will support the conclusion that it is a variable of a wide range of value, changing continually with a slight variation in the condition of the fire. The quality of the coal, whether coarse or fine, coking or non-coking, would also modify it. It is interesting to note that Professors Gale and Thurston arrived independently at the conclusion that the value of G is variable, and is approximately in inverse proportion to the square of the absolute temperature of the chimney ($t_1^2$). Professor Thurston places $G = \frac{a^2 t_2^2}{t_1^2}$, in which a is a constant, usually not far from 2 and $t_2$ is the absolute temperature representing the mean within the fire. He concludes that the temperature of maximum delivery is a variable quantity "far above that ordinarily taken as that of good practice in the operation of the steam boiler."

Mr. Thomas Box says that "the maximum effect is attained when the volume of the internal air is between three and four times that of the external air * * *. If we admit 3½ as the relative volume, the temperature would be about 1300 degrees." In 1889, Professor H. B. Gale concluded after many experiments that "The ordinary values of the temperature of maximum draught would range from one thousand to two thousand degrees on the common Fahrenheit scale." In 1890, Professor R. H. Thurston arrived at the conclusion that "both the facts of experiments and the deduction of our theory confirm the proposition that the maximum draught in the sense in which the term is here used (that of maximum delivery, not of maximum intensity) ordinarily, if not invariably, occurs at a temperature far above that previously supposed; that

maximum rising as the resistance at the grate increases and as the resistance in the stack decreases. It is probably rarely found at temperatures less than 700° or 800°, or very probably 1,000° Fahrenheit." And again: "No maximum draught is likely to be approached at any temperature occurring in the chimney, the actual maxima falling more commonly at points on the scale between 800° and 2,000° Fahrenheit."

It therefore seems quite well established that the maximum draught is not reached at a temperature of 600° Fahrenheit, although it is none the less true that the temperature of the stack in practice should rarely, if ever, be allowed to exceed that figure. If greater draught is needed to burn the required amount of fuel there will be some gain in raising the temperature within the stack even above 600°. Such procedure, however, is very uneconomical and is to be avoided, especially in view of the fact that the draught power approaches the maximum slowly, considerable increase in temperature being followed by only a small gain in power.

With a heating surface properly distributed and in correct proportion to the grate surface, the temperature of the gases may be made to approach closely to that of the water in the boiler, the height of chimney giving a head sufficient for draught instead of a high and wasteful internal temperature.

## MICHIGAN ENGINEERS IN THE WAR.

In connection with the register of alumni of the Engineering Department, it is thought fitting to make special mention of both the graduates and undergraduates of this department, who were connected in various ways with the Spanish war last year. The place, the duty, and the services performed by those who were engineers were in many cases little thought of and never mentioned in the newspapers and magazines, but the engineer's work was of none the less importance because of this lack of publicity.

The work done by the crew and naval reserves, many of whom were from the Engineering Department, and of no experience at sea whatever, on the Yosemite, where there was an immense amount of work to be done to get the ship in readiness; the intelligence and efficiency with which that work was done; and the remarkably short time in which they trained down to good fighting men, has been the subject of considerable mention by officers in charge.

Those whose duties were of great importance and no glory are to be remembered as well as those who saw active service. Nor must be forgotten those who have enlisted and whose companies were not called out. The spirit of self-sacrifice and duty to our country was alike in all.

The following is a list of the men with the positions they held:

First is Mortimer E. Cooley, Professor of Mechanical Engineering, who was assigned as chief engineer to the U. S. S. Yosemite. He was in charge of transforming the vessel to a cruiser and fitting her for active service. He held the position of Chief Engineer through the war and until February of the present year. It was a fitting tribute to Professor Cooley's work and a recognition of his ability when the Yosemite was selected by the government as the most efficient and best conditioned of any of the auxiliary cruisers for foreign service, to go to Guam island, in the Ladrones.

BAKER, WM. P., '99, Woodville, O.—Private Co. A., 31st Mich. Vol. Inf. Honorably discharged October 13th to return to college.

BURNSTINE, ALBERT, '88, East Berlin, Conn.—Lieutenant, junior grade, U. S. Navy; executive officer U. S. S. Apache.

BUSH, PLATT R., '95, Saginaw, Mich.—Civil engineer, at work on Fort Jackson, La. Died at Harper Hospital, Detroit, October 4, 1898. The work on the defenses at Forts Jackson and St. Phillip was being rushed night and day. Mr. Bush was on night duty, and the hard work and exposure undoubtedly had something to do with making him less able to resist disease. The immediate cause of death was a malignant tumor, affecting the brain.

CAMPAU, MELANCTHON WOOLSEY, '97, Detroit—Water tender U. S. S. Yosemite.

CHANDLER, GEORGE MOSELEY, ex—'98, Chicago—Ordinary seaman U. S. S. Yosemite.

CHURCH, E. N., ex—'99, Alma, Mich.—35th Mich. Vol. Inf.

CONKLIN, JESSE I., '95, Springport, Mich.—Civil Engineer at work on Forts Jackson and St. Phillip, La.

DAVIS, FRANK P., '76, Valleyfield, Que.—U. S. Ass't Engineer, Supt. of Improvements for U. S. Navy at Dry Tortugas, Fla.

DONOVAN, CORNELIUS, '72—U. S. Ass't Engineer, at work at Forts Jackson and St. Phillip, La.

EDDY, CHAS. MORTON, '96, Toledo, O.—10th Ohio Vol. Inf., stationed at Augusta, Ga.

GILLETT, GEORGE FRANCIS, ex—'97, Saginaw, Mich.—Seaman, U. S. S. Yosemite.

GOWAN, HENRY CARLTON, '01, Sault Ste. Marie, Mich.—Private Co. G, 34th Mich. Vol. Inf. Died of typhoid fever at Grace Hospital, Detroit, September 17, 1898.

HAYLER, JR., GEORGE, '94, Van Wert, O.—Company clerk, Co. D, 2d Ohio Vol. Inf. Recruiting officer for regiment. Ill seven weeks with typhoid fever at Knoxville, Tenn.

HECKER, FRANK CLARENCE, ex—'92, Detroit—Boatswain's mate, second class, U. S. S. Yosemite.

[illegible], Theodore Henry, '93, Detroit—Chief machinist, U. S. S. [illegible].

[illegible], Byron Dexter, '95, Detroit—Chief Electrician, U. S. S. [illegible].

[illegible], Charles Arthur, '92, Detroit—Ordinary seaman, U. S. S. [illegible].

[illegible], John Henry, ex—'97, Port Huron, Mich.—Private, Co. L, [illegible] Mich. Vol. Inf. Colonel's orderly. Enlisted June 2, 1898, at [illegible] Lake. Was under fire with company, July 2-8, at San Juan [illegible].

[illegible], Louis, '97 Barberton, O.—Ordinary seaman, U. S. S. [illegible].

[illegible], Berkey, ex—'99, Grand Rapids, Mich.—Captain Co. G, 32d [illegible]. Vol. Inf.

[illegible] Jones, '01, Detroit—Ordinary seaman, U. S. S. Yosemite. [illegible] to college.

[illegible], Wm. Leaster, '99, Ypsilanti—Private Co. A, 31st Mich. Vol. [illegible]. Honorably discharged by petition October 13th to return to [illegible].

[illegible], Wm. Lewis, ex—'97, Detroit—Corporal Co. I, 31st Mich. Vol. Inf. [illegible] out in May, 1899.

[illegible], George Edward, ex—'98, Escanaba, Mich.—Private Co. G, [illegible] Mich. Vol. Inf. Honorably discharged.

[illegible], Fred Richard, '96, St. Paul—Sergeant Co. G, 2d U. S. [illegible] Engineers. Joined at St. Paul, June 24, 1898. Stationed at [illegible] Sheridan, Ill., until August 10th; Montauk Point, until October [illegible]; Huntsville, Ala., until mustered out, October 20.

[illegible], S. C., '80, New York City—Enlisted as private in Gatling Gun [illegible], of New Jersey. Company volunteered in a body to governor, [illegible] were not called out.

[illegible], Chas. A., '65, U. S. Ass't Engineer on Fortifications at mouth of [illegible] Mississippi. First Lieutenant, 3d U. S. Vol. Engineers.

[illegible], Chas. J. Holland, '97, Sault Ste. Marie—Electrician U. S. S. [illegible].

[illegible], Harry C., ex—'00, Detroit—Enlisted as private, promoted to [illegible]geant Co. L, 31st Mich. Vol. Inf. Mustered out in May, '99.

[illegible], Herbert A., '98, Muskegon, Mich.—Passed examination July [illegible]898, for Ass't Engineer in U. S. Navy at Charlestown Navy Yard, [illegible] Boston, but was too late for appointment.

[illegible], Walter R., '88, Detroit—Ensign U. S. Navy; assigned to [illegible]mite.

[illegible], Wm. Post, '94, Pittsburgh—Color Sergeant, 1st U. S. Vol. Engi[illegible]rs. Stationed in Porto Rico.

QUINN, RICHARD, '94—U. S. Ass't Engineer, in charge of fortification works at Forts Jackson and St. Phillip, La.

ROBEN, DONALD BENNETT, '01, Big Rapids, Mich.—Private Co. A, 34th Mich. Vol. Inf. Returned to college.

RYAN, EDW. JAMES, '96, Detroit—Machinist, second class, U. S. S. Yosemite.

RUSSEL, ALBERT WELLS, ex—'96, Detroit—Ordinary seaman, U. S. S. Yosemite.

STEKETEE, LEANDER WINSLOW, ex—'95, Grand Rapids, Mich.—First Sergeant Co. G, 32d Mich. Vol. Inf.

STRINGAM, JOSEPH, '98, resident graduate, Detroit—Jack 'o dust, U. S. S. Yosemite.

UDELL, LOUIS, '02, Muskegon, Mich.—Quartermaster Sergeant, Co. C, 34th Mich. Vol. Inf.

VLADIMIROFF, THEODORE, '97, U. S. S. Helena. Engineer, second class. To Manila via Suez canal.

WHALEN, MALCOLM, ex—'98, Ludington, Mich.—Private. Co. A, 35th Mich. Vol. Inf.

WEBSTER, CHAS. DELMAR, '97, Bay City, Mich.—Corporal Co. C, 33d Mich. Vol. Inf. Also in Co. K, 3d U. S. Vol. Engineers.

WELLS, HEBER A., ex—'98, Carthage, Mo.—First Sergeant, Co. A, 2d Mo. Vol. Inf. Encamped at Camp Thomas, Tenn., Camp Hamilton, Ky., Camp Albany, Ga. Ordered to Matanzas by January 1, 1899.

WINCHELL, CHARLES MCALLISTER, '73, Newport, R. I.—Before and during the war was engaged on fortifications in Narragansett Bay.

WOODRUFF, EDWIN FRANCIS, '96, Ludington, Mich.—Acting U. S. Ass't Engineer in the Navy with rank of ensign. Died June 3, 1898, from injuries received in jumping from a moving train at Ludington, when returning home from Philadelphia on leave of absence after having passed an examination for the navy.

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## MEMORANDUM REGARDING THE COLORING OF PIPING IN THE UNITED STATES NAVY.

The contents of the pipe, whether steam, fresh water, salt water, etc., will be indicated by a colored band, about eight inches long on each side of flanges and couplings, being painted *red* or *black*, in accordance with the following instructions:

The color of the bands will be:

| | |
|---|---|
| Steam piping | White. |
| Salt water (steam pump) | Green. |
| Salt water (hand pump) | Grey. |
| Fresh water (steam pump) | Blue. |
| Fresh water (hand pump) | Blue. |
| Ventilation ducts | Yellow. |
| Firemain | Red. |
| Drainage system | Pink. |
| Flooding system | Pink. |

The coloring of the faces of the flanges and couplings is determined thus:

A steam pump, a hand pump, a steam engine, a ventilating blower, a distiller, a hydrant on shore, or a fresh water distributing tank being considered a machine.

The supply or suction to such machine will be marked BLACK, and the exhaust, discharge or delivery from such machine will be marked RED.

On drainage and flooding piping the red and black faces are omitted.

## EDITORIALS.

We have endeavored to present our *Technic* to its readers as early as have the boards of the last two years. However we have found the compilation of the data and material for the Alumni Register to be an enormous task, and as we wished to offer it with as few errors as possible we have delayed the publication so as to make the records more complete.

The account of our Alumni who took part in the late American-Spanish war will be of interest to all our engineering graduates. It shows that our department took no small share in aiding the country both on land and on sea.

In presenting the Register of Alumni we have followed in the steps of the board of the '96 *Technic*. It has been impossible in the short time that we have had to do the work to make the list absolutely perfect and complete. As for its merits we will let the Register speak for itself. Upon the suggestion of several prominent alumni we have published the names in alphabetical order instead of by classes as was done in the former list, believing this will greatly facilitate reference.

The question of procuring prominent engineers from various sections of the country to speak before our Engineering Society has been very strongly advocated this past year. The successes attendant upon the lectures by Prof. A. H. Sabin and Mr. Walter B. Snow would seem to indicate that such a movement would certainly be in the right direction. Let our Alumni help the Society in this undertaking and do all they can to bring themselves or to persuade others to appear before our meetings. The president and other officers of the Society would be very glad to correspond with any who have their services or suggestions to offer.

The scheme to change the publication of *The Technic* from an annual to a quarterly has been brought forward this year as in past years. The Engineering Society, however, is very reluctant to take the step at present, although with sufficient encouragement from the Alumni and Faculty such a step might be advantageous to all concerned.

*The Technic* is indebted to the Alumni Association of the University for valuable assistance lent the board in the preparation of the Alumni Register and the War Article.

We would respectfully request our readers to pay special attention to our advertising pages. The firms represented in this issue are of the highest standing and it is to their patronage that the success of *The Technic* is largely due.

**BURR HARDY**

*Born January —, 1875.*
*Died in Ann Arbor, Mich., January 3, 1899.*

**FREDERICK LEWIS BROWNE.**

*Born at Bay City, Mich., February 24, 1878.*

*Drowned at Whitmore Lake, Mich., April 30, 1899.*

NTH . . . . . .

INUAL BANQUET

OF THE

ENGINEERING SOCIETY

OF THE

UNIVERSITY OF MICHIGAN.

+ + + +

y Evening,
2, 1899. - - - Elks' Hall.

COMMITTEE.

*M. B. Beattie, Chairman.*

*Emanuel Anderson, '99*

*W. M. McKee, '99*

*F. I. Wilbur, '00*

*S. P. Cobb, '00*

*G. D. Hudnutt, '01*

*W. C. Swartout, '01*

*J. O. Emerson, '02*

*Bachtel, '02*

**MUSIC.**

Welcome, . . . . . PRESIDENT

"A good dinner to lubricate business."

Address by the President, . JAMES C. ARMSTRONG

# TOASTS.

Toastmaster. CHAS. A. LaFEVER.

"While you may twitch at your collar and wrinkle
your brow,
But you're up on your legs and you're
in for it now."

1902 . . . . . F. W. CUMMER

"The eagle suffers little birds to sing."

1901 . . . . . F. W. LANCASHIRE

"The opening promise of genius to be."

1900 . . . . . P. A. DRATZ

"With faith in what I hope to be,
Not in what I have been."

1899 . . . . . E. W. CONABLE

"We end only to begin."

**YELLOW AND BLUE—GLEE CLUB.**

The Technic, . . . . . C. W. WHITNEY

"Books should to one of these four ends conduce,
For wisdom, piety, delight or use."

PROF. C. E. GREENE

"From whom all blessings flow."

MR. C. G. WRENTMORE

"Excelled by none as judge
Of Nature's curves and curls."

**MUSIC.**

PROF. H. S. CARHART

"Go on fair science; soon to thee
Shall Nature yield her idle boast."

DR. J. W. GLOVER

"How mathematics turn all students pale,
Yet holds the eel of science by the tail."

PROF. M. E. COOLEY

"Not a chip of the old block,
But the old block itself."

**SONG: ANN ARBOR—GLEE CLUB.**

# Second . . . . . Annual Banquet

OF THE

# UNIVERSITY OF MICHIGAN ENGINEERS

...OF CHICAGO...

Saturday Evening, May 20, 1899.
At the Technical Club.

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## COMMITTEES.

TOASTMASTER–
L. K. Comstock, '89

BANQUET–
A. K. Adler, '94
D. B. Cheever, '91
C. E. DePuy, '91

INVITATION–
A. M. Haubrich, '95
George A. Damon, '95
R. P. Lamont, '91

GENERAL CHAIRMAN–
E. N. Cheney, '92

PROGRAM–
C. G. Atkins, '93
H. W. Wyckoff, '95
G. A. Springer, '90.

PRESS–
H. M. Cox, '95
F. S. Richmond, '91
F. Sackett, '96.

This banquet marked a very enjoyable event in the social lives of the Chicago Alumni of our Engineering Department. Out of about one hundred and thirty engineers who are located in Chicago or its vicinity sixty were present. There were also in attendance Professors M. E. Cooley and H. S. Carhart and Dr. K. E. Guthe, of the University, Professor R. C. Carpenter, '75, now of Cornell University, Professor F. C. Wagner, '85, now of Rose Polytechnic Institute, and Professor Fred Morley, '86, now of Purdue University. After the banquet the following program was begun with the U. of M. yell:

YELLOW AND BLUE.

"The Naval Militia," . . Professor M. E. Cooley

"A Tree is Known by its Fruits," Professor H. S. Carhart

SONG: REMINISCENCES.

"The Possibilities of a Liquid-Air Engine,"
. . . . Professor F. C. Wagner, '85

"Engineering Features in Mexico," T. P. Gaylord, '94

"Ann Arbor," . . . Walter F. Cahill, '96

SONG: ANN ARBOR.

During the evening a committee that had previously been appointed to consider a permanent organization, reported, recommending the organization of the Chicago Alumni Engineers' Association of the University of Michigan. They were to have no constitution nor by-laws but should have two objects, one being to hold two social affairs annually, and the other being to help the Engineering Department of the University in every way possible. The furtherance of these objects was to be left in the hands of two officers, one a president with power to appoint committees, and the other a secretary-treasurer, who should act as a high grade technical agency in helping engineering graduates desirous of locating in the vicinity of Chicago to secure employment. The committee's report was unanimously adopted and Mr. Robert P. Lamont, '91, chosen as president. The secretary has not been chosen as yet.

# REGISTER

..of the..

# ENGINEERING ALUMNI

..of..

## THE UNIVERSITY OF MICHIGAN.

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NOTE.—The degrees of Civil Engr. and Mining Engr. were given until 1867, at which time the degrees of B. S. (C. E.) and B. S. (M. E.) were substituted. The degree of B. S. (Mech. E.) was first given in 1883, and that of B. S. (E. E.) in 1890.

### HONORARY DEGREES.

1879.

ORLANDO B. WHEELER, C. E., A. B., '62. See also Alumni list.

1884.

CHARLES E. GREENE, C. E. A. B. (Harvard Univ.), '62. B. S. (Mass. Inst. of Tech.), '68. Prof. of Civil Eng. and Dean of the Department of Engineering, Univ. of Mich.

1885.

THOMAS E. COOLEY, Mech. E., Graduate U. S. Naval Academy, '78. Prof. of Mech. Eng., Univ. of Mich.

### ALUMNI.

A

WALTER SCOTT ABLE, '78 M. E. Min. Engr. Assay Office, San Francisco; died at San Francisco, May 23, '87.

ABRAHAM KOHN ADLER, '94 B. S. (Mech. Engr.). With McDonald Eng. Co., '94-'95; with Crane Elevator Co., '95-'96; Mech. Engr. with D. Adler, Archt., '96-'99. 64 Auditorium Bldg., Chicago, Ill.

JOHN HENRY AIKINS, '77 C. E. First Asst. Engr. Monarch Pass, G. & D. R. R. '79-80; Division Engr. B. & Mo. R. R. R., '87; U. S. Deputy Mineral Surveyor; Asst. General Manager Magna Charta Silver Mining and Tunnel Co., '91-'93; Mining Engr.
Drawer G, Gunnison, Colo.

HORACE CLEMENT ALEXANDER, '82 (Non Grad.). Engr. Lincoln Park Blv'd; Cons. Eng. with Alexander & Shaw; Engr. of water pipe extension.
323 City Hall, Chicago.

HUGH BYRON ALEXANDER, '69 C. E. and M. E. Asst. Engr. Sanitary District of Chicago. Geneva, Ill.

DeWitt Clinton Allen, '76 C. E. Surveyor and Farmer.
Cattaraugus, N. Y.

John Robins Allen, '92 B. S. (Mech. E.), '96 Mech. E., Jun. Am. Soc. Mech. E. Const. Engr. for Bay City Industrial Works; Secy. Louis K. Comstock Co.; Consulting Engr., Chicago; Prof. of Mechanics and Electricity Y. M. C. A. Evening College, Chicago; Instructor U. of M. 226 S. Ingalls St., Ann Arbor, Mich.

Geo. Franklin Allmendinger, '78 C. E. Mngr. Delhi Mills; do. A. A. Fruit and Vinegar Co.; do. A. A. Milling Co. Ann Arbor, Mich.

Elmer Louis Allor, '92 B. S. (C. E.), '95 LL. B. Instr. Astronomy U. of M., '92-'93; Recorder U. S. Lake Survey, '93-'94; Attorney-at-law. 710 Union Trust Bldg., Detroit, Mich.

Edwin Eugene Ames, '85 (Non Grad.). Asst. Eng. U. P. R. R. '85-'86; Asst. Engr. Santa Fe and B. & M. R. R.; Draughtsman Surveyor Genl's Office; U. S. Deputy Mineral Surveyor. Cripple Creek, Colo.

George Marshall Ames, '85 (Non Grad.). Rodman, Grand River Survey, Grand Rapids, '85; Levelman, A. T. & S. F. R. R., '86; Asst. City Engr., Grand Rapids, '86-'96; Acting City Engr., '96-'98; City Engr. '98 to date. City Hall, Grand Rapids, Mich.

Robert Lewis Ames, '94 B. S. (Mech. E.). Draughtsman, St. Ry. Co., Grand Rapids; Draughtsman, City Engr. Office, Kalamazoo, '92; U. S. Lake Survey, '93-'94; Asst. Examiner, Patent Office, '94 to date. Washington, D. C.

Frank Anderson, '90 B. S. (C. E.). Civil and Mining Engr.
Salt Lake City, Utah.

Louis Warner Anderson, '95 B. S. (C. E.), B. S. (Albion.). Recorder U. S. Harbor Surveys, '95; Inspr. U. S. Harbor Surveys, '95-'96; Asst. City Engr., Grand Rapids, '97 to date.
24 Eureka Avenue, Grand Rapids, Mich.

Albert Llewellyn Arey, '75 C. E. U. S. Asst. Engr. Mississippi River Improvement, '75-'76; Locating Engr. Gt. N. R. R.; Division Engr. C. M. & St. P. R. R., '77-'80; Professor Physics and Chemistry, Rochester Free Academy, '85-'99; Professor Chemistry, Rochester Mechanics' Institute, '97-'99. 229 Averill Ave., Rochester, N. Y.

*Clarence Oliver Arey, '78 C. E., M. D. (U. of Penn.). In charge of Bacteriological Lab. Govt. Experiment Station, '93; Architect; Died at Cleveland, O., Aug. 11, '96.

Chas. Gillman Atkins, '93 B. S. (E. E.). First Asst. Engr., Westinghouse Co., '93-'95; Constructing Engr., Westinghouse Co., New England district; Supt. Chicago Edison Shops.
76 Market St., Chicago, Ill.

Walter Merville Austin, '95 B. S. (E. E.). With Storey Motor and Tool Co. Trenton, N. J.

John Ayers, '80 M. E. Cashier in bank '81-'82; Firm of Ayers & Co., Wholesale Hardware, '82 to date.
513 Garrison Ave., Fort Smith, Ark.

[illegible] Wiley Baggott, '99 B. S. (C. E.). With U. S. Scale Co., '98; Lake Sup. Power Co. Sault Ste. Marie, Mich.

[illegible] Franklin Bailey, '98 B. S. (E. E.). With Edison Illuminating Co., Detroit, '98-'99; General Electric Co., '99 to date.
323 Summit Ave., Schenectady, N. Y.

[illegible] Seymour Baillie, '90 B. S. (C. E.). Vice President and General Manager Columbia Gold Mining Co. Sumpter, Oregon.

[illegible] Marion Bain, '68 C. E. Asst. Eng. C. & A. R. R.; Transitman, Bellaire & S. W. R. R. 514 Forest Ave., Ann Arbor, Mich.

[illegible] Baird, '96 (Non Grad.). With Moulton Starrett Co., '96-'97; Time keeper, Engr. and Supt. with Geo. A. Fuller Co., '98-'99.
160-5th Avenue., New York City.

[illegible] Joseph Baker, '87 B. S. (Mech. E.). Western representative, United Traction Co., Chicago; Secretary Hammond Light & Power Co.; Attorney-at-law. 1119 Chamber of Commerce Bldg., Chicago, Ill.

[illegible] Louis Baker, '97 B. S. (Mech. E.). Elec. Lighting, U. of M. '97; Machinist M. C. R. R. Shops, '97-'98; Draughtsman, Schen. Loco. Works, '98 to date. 931 State St., Schenectady, N. Y.

[illegible] Williams Baker, '77 C. E. M. Am. Soc. C. E. U. S. Asst. Engr. Miss. & Mo. River Imp't. Civil Engineer. St. Louis, Mo.

[illegible] Baker, '75 C. E. L. M. & B. R. R., '75-'76; Teaching, LaFayette, Ind., '76-'77; Supt. Schools, Owosso, '77-'78; Manufacturing, Petoskey, '81-'82; Teaching Math. Berkley, Cal., '81-'82; Asst. Engr. C. P. R. R., '82-'83; Assistant in U. S. Magnetic Observatory, Los Angeles, '83-'84; Manf., '84-'85; Fruit grower '87 to date. Drawer 2598, Fresno, Cal.

[illegible] Baker, 70 A. B., '76 A. M. Prof. Math., Albion Coll., '70-'71; Instructor Math., U. of M., '71-'73; U. S. Coast and Geodetic Survey, '75-'86; Cartographer, U. S. Geol. Survey; Cartogr. Venezuelan Boundry Comm.; at present Cartogr. U. S. Geol. Survey.
1905-16th St., Washington, D. C.

[illegible] Everton Baldwin, '71 C. E.

[illegible] Cutler Baldwin, '75 C. E. U. S. Mineral Surveyor, Leadville, Colo., '75-'86. Died at Leadville, Nov., 1886.

[illegible] Baldwin, '93 B. S. (C. E.). Asst. Engr. M. of Way, C. C. C. and St. L. Ry., '93-'96; Supervisor of Track do.; Engr. M. of W. do.
Indianapolis, Ind.

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[illegible] Brown, '98 B. S. (E. E.). With C. R. I & P. Ry.; do. Chicago [illegible] Co.; at present Draughtsman Cutter Hammer Mfg. Co.
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HARVEY GOULD GILKERSON, '95 B. S. (C. E.). Engr. Corps. St. L. & K. C. R. R., '95; Transitman, Col. Springs & Cripple Creek R. R. Colorado Springs, Colo.

FRANCIS FAIR GILLEN, '98 B. S. (C. E.). Recorder, U. S. Deep Waterways Survey, '98; Insp. Mich. Lake Superior Power Co., '98; Engr. Asst., Dept. Bldgs. and Grounds. Washington, D. C.

*JOSHUA LATHROP GILLESPIE, '71 C. E., '72 Ph. B. U. S. Asst. Engr. Falls of St. Anthony, Minn., '73–'77; do. Miss. Riv. Imp.; Civ. Eng.; Died at Hartford, Conn., Aug. 22, '90.

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[illegible] Paxson Goodrich, '98 B. S. (C. E.). Edison Illum. Co., Detroit, '98; Engr. Asst., Bldgs. & Grounds, Washington, D. C., '98; Civil Engineer, U. S. Navy. Brooklyn, N. Y.

[illegible] Jay Goulding, '93 B. S. (Mech. E.). Inst. in Drawing, U. of M. Ann Arbor, Mich.

[illegible] Paul Grace, '96 B. S. (E. E.). Electrical Engr., Detroit Telephone Co. 887–15th St., Detroit, Mich.

[illegible] Warren Grant, '75 C. E., M. Am. Soc. C. E. Mo. River Imprvt., '79; Res. Engr. A. T. & S. F. Ry., '80 '87; Office Engr., Ft. W. & R. G. R. R.; Locating Engr., C. T. F. & C. R. R.; Asst. Engr., A. T. & S. F. Ry., Carrollton, Mo.; Res. Engr. do. East Las Vegas, N. W.

[illegible] Lincoln Green, '91 B. S. (C. E.). Asst. Engr. Merchant's Bridge, St. Louis; do. Terminal Ry.; Eng. Sec'y E. L. Corthell, '91–'92; Asst. Chief Engr. Tehuantepec Nat'l R. R., Mexico, '92–'93; Asst. Engr. Congress'l Library, '93–'94; Asst. Engr. N. O. Bridge, '94; Asst. Engr. Osborn Co., '94–'96; Member above firm, '98–'99. Osborn Bldg., Cleveland, O.

[illegible] May Green, '98 B. S. (Mech. E.). Draughtsman, Detroit Htg. & Ventil. Co. '91–'92; do Elec. Wks. '93; do. Frontier Iron Wks. '93; do. Russell Wheel & Foundry Co. '95–'96; Insp. Mich. Lake Superior Power Co. 304 Spruce St., Sault Ste. Marie, Mich.

[illegible] Emerson Greene, '96 B. S. (C. E.), '95 Ph.B. Cement Tests, Burr's Island Dam, '96; Asst. U. of M., '96–'97; Draughtsman Detroit Bldgs. & Iron Wks., '97–'99; Asst. Engr. M. of W., M. C. R. R., '99. 40 Forest Ave. W., Detroit, Mich.

[illegible] Greulich, '94 B. S. (C. E.). Arch. Draughtsman, '94–'95; do. National Blower Co., '95–'96; do. Illinois Steel Co., (Milwaukee), '96; Htg. & Ventil'g Engr. for Wm. Bagley & Sons Co., '97 to date. 176 S. Bay St., Milwaukee, Wis.

[illegible] Murdock Groesbeck, '93 B. S. (M. E.). With Chgo. Carpet Co. Chicago, Ill.

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EDWIN WILLIAM GROVES, '86 (Non Grad.). Survey of Upper Miss. River, '87; Asst City Engr. Dallas, Tex., '88–'89; Asst. Engr. Board of Public Works, Austin, Tex., '89–'91; Chief Engr. do. '91-'93; General Engineering Work, '93–'98; Engineer for Rapid Railway, Detroit, 1899.
110—12th St., Ann Arbor, Mich.

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DWIGHT MAY GUILLOTTE, '96 B. S. (Mech. E.). With Master Mech. and Erecting Dept. A. A. R. R., Owosso; do. Iron & Silver Mining Co.
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HENRY D. HAMPER, '94 B. S. (Mech. E.). Asst. D. L. Barnes, Cons. Engr.; With Western Wheeled Scraper Co. 26 S. Root St., Aurora, Ill.

*WM. ROY HAND, '87 B. S. (C. E.). With Vierling, McDowell & Co.; Draughtsman P. E. Lane, Chicago; West. Agt. Lane Bdge. and Iron Wks., Denver; Prof. of Eng., School of Mines, Colo. Died at Denver Oct. 17, 1895.

HERBERT OSBORNE HANFORD, '98 (Non Grad.). Draughtsman, Detroit Water Works. Detroit, Mich.

JOHN K. HANSON, '78 C. E. Civil Engr. Concord, Neb.

CHAS. JACOBSON HARMON, '94 B. S. (C. E.). Elec. Equip. Dept. Metropolitan Elev. R. R., Chicago, '94–'96; Com'l Traveler with Morgan & Wright, '97–'98; do. Ames & Frost Co., Chgo., '98 to date.
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Hatch, '92 B. S. (C. E.). Draughtsman Philadelphia, '92-'93;
th. and Civil Engineering Mich. Agricultural College, '93-'94;
r. Maintenance of Way C. C. C. & St. L. Ry., '94-'95; Struc-
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Van Wert, O.

n Haywarn, '70 C. E. U. S. Harbor Survey, '73; U. S.
gr., Galveston Harbor. Drowned near Texas Coast Aug.

ad, '73 C. E. Sturgeon Bay & Lake Mich. Ship Canal,
ed Heim Brewing Co., Kansas City, '72-'76; Manager of a
e. Illinois and St. Clair Sts., Chicago, Ill.

ch Heckler, '89 B. S. (C. E.). Chief Engineer Mattheissen
Zinc Co. La Salle, Ill.

n, '82 B. S. (C. E.). (Mrs. Paul Carus.) La Salle, Ill.

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resdt. Cherokee Coal Mining Co.; Supt. and Chief Engr. H.
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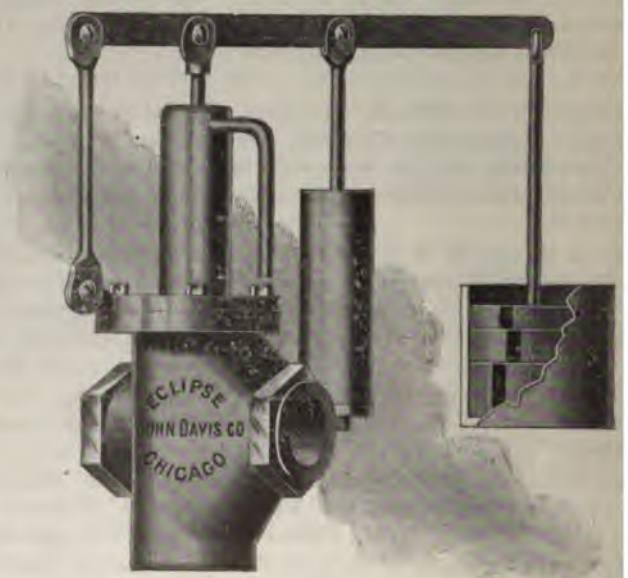


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[illegible] George Heyzer, '86 B. S. (C. E.). Div. Engr. C. B. & Q. R. R. '86-'91; Roadmaster '91 to date. Canal and 16th, Chicago, Ill.

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[illegible] B. Hoover, '87 B. S. (C. E.). Supt. Schools Le Seur, Minn., '87-'89; Prin. Normal Department University N. Dakota, '90-'92; Sec'y Educational Department International Committee Y. M. C. A., '92 to date.
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Died at Buffalo, N. Y., Oct. 1, 1898.

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Edward Bishop House, '96 B. S. (E. E.). Professor of Mathematics, Col. Agl. College. Ft. Collins, Col.

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Allan Melanchthon Hurff, '69 (Non. Grad.). Div'n Engr., C. V. L. & N. R. R.; Druggist and Life Insurance. Carthage, Mo.

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Lorenzo Hutchinson, '97 B. S. (E. E.). Seaman, C. S. S. Yosemite, '98; at present, Draughtsman and Testing Boilers, Sterling Boiler Co.
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HENRY WICK JUDD, '78 M. E. Cashier Wick Banking and Trust Co.
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ELMER HARTSON NEFF, '90 B. S. (Mech. E.), M. Am. Soc. M. E.; Constructing Eng. E. P. Allis & Co.; Chief Draughtsman Gisholt Machine Co.; Draughtsman Westinghouse Elec. & Mfg. Co.; Instructor Mech. Engr. Purdue Univ.; Draughtsman Western Gas Construction Co.; Designer Brown & Sharp Mfg. Co., N. Y.; Representative of Brown & Sharpe Mfg. Co. 136 Liberty St., New York.

JAMES BURTON NELSON, '90 B. S. (C. E.). Survey S. E. Kentucky, '90–'91; Bridge and Structural Iron Works, Chgo., '91–'94; Consulting Engr., Indpls., '94 to date. Secy. Indiana Engrs. Soc., two years. 61 Baldwin Blk., Indianapolis, Ind.

Wm. Frederick Valentine Neumann, '97 B. S. (E. E.). Lineman Electric Road, Dayton, O.; do. Chase Const'n Co., Detroit. Romeo, Mich.

Edgar Clifton Newell, '92 B. S. (E. E.). In charge Manual Training Dept., Pueblo H. S., Pueblo, Col., '92-'94; Prof. Mech. Drawing and Manual Training, Des Moines H. S., '94 to date.
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Seaton George Newton, '98 B. S. (C. E.). Draughtsman U. S. Deep Waterways Survey, '98; Draughtsman Gen'l Electric Co., '98 to date. 540 Liberty St., Schenectady, N. Y.

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Martin Luther Newton, '75 C. E. Prin. H. S. La Porto City, Ia., '76-'78; dit., '82-'85; Chief. Engr. D. I. & D. Ry. Co., '87-'88; County Surveyor Black Hawk Co., '89 to date; Chief Engr. W. C. & F. Rapid Transit, '96 to date. 617 Mulberry St. Waterloo, Ia.

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John Francis Nichols, '95 B. S. (Mech. E.). Machinist, F. W. Wheeler Co., '95; Draughtsman do., '95-'97; do. Industrial Wks., Bay City, '97-'98; do. Newport News Shipbuilding & Dry Dock Co., '98 to date. 613 Jackson St., Newport News, Va.

Alfred Noble, '70 C. E., '95 hon. LL.D., M. Am. Soc. C. E. U. S. Asst. Engr. charge St. Mary's Falls Canal and St. Mary's River, '70-'82; General Supt. do., '81-'82; Resident Engineer Shreveport Bridge, '82-'83; General Asst. Engr. N. P. R. R., '82-'86; Res. Engr. Washington Bridge, '86-'87; do. Cairo Bridge, '87-'89; do. Memphis Bridge, '89-'92; Asst. Chief. Engr. Bellfontaine, Alton and Leavenworth Bridges, '92-'94; Member Nicaragua Canal Commission, '95; dit. U. S. Board Engineers on Deep Water Ways, '97-'99; President Western Society Engineers, '98; Civil Engr.
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Iron Mountain, '84–'85; Engr. and Chemist, Ironwood, Mich., '85-'90;
Supt. Colley Mine, Bessemer, '90–'92; Gen'l Supt. Penokee Gogebic
Consol. Mines, '92–'94; Gen'l Supt. Rockefeller interests on Mesaba
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CLARK OLDS, '70 B. S., '73 M. S. U. S. Ass't Engr. Lake Survey, '70–'73;
Water Works Com'r, Erie, Pa.; Att'y at Law. Erie, Pa.

FAY DEVEAUX Olmstead, '97 (Non Grad.). Detroit, Mich.

EDWARD BEEKMAN OLNEY, '86 (Non Grad.). In U. S. Weather Bureau
up to 1893. Later on a ranch in California. Present whereabouts
unknown.

FRANK BURT OLNEY, '91 (Non Grad.). With City Nat'l Gas Dept., Toledo
'91; member firm of Gov't Contractors of C. E. Mitchell & Co., '91;
Dry Goods business. Ludington, Mich.

HENRY BAILEY OTIS, '96 B. S. (E. E.). Chicago Telephone Co., '97;
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## P

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Bridge Works, Chicago, '94–'95; do. New Columbus Bridge Co.,
Columbus, O., '95; do. Elmira Bridge Co., Elmira, N. Y., '95–'96; do.
Hamilton Bridge Co., Ltd., '96 to date.
68 George St., Hamilton, Ont.

*GEORGE EVERT PANTLIND, '75 C. E., '78 LL.B. Lumber Dealer, Grand
Rapids, died in Chicago, March 23, '96.

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912 Chamber of Commerce, Detroit, Mich.

[illegible] PARKER, '94 B. S. (C. E.). Draughtsman Detroit Heating [illegible]ighting Co.; do. Detroit Metal and Heating Co; Detroit Dry [illegible]Co.; Kenwood Bridge Co., Chicago; do. Whiting Foundry Co., [illegible]y, Ill.; do. Massillon Bridge Co.; do. Pittsburg Bridge Co.; [illegible]arnegie Steel Co., Ltd.; do. Keystone Bridge Works; Color [illegible]and 1st U. S. Vol. Engineers. 4629 Fifth Ave, Pittsburg, Pa.

[illegible] PARKS, '88 (Non Grad.). With Sherwin-Williams Paint [illegible]0 to date. Now Gen'l Sales Manager of above Company.
100 Canal St., Cleveland, Ohio.

[illegible]NELAS PARR, '86 (Non-Grad.). Transitman, C. S. & St. L. R. R., [illegible]Rodman, C. St. L. & P. R. R., '87-'88; Levelman, M. R. & B. T. [illegible], '89; Ass't Eng. American Association, Ltd., '90-'92; Chief Eng. [illegible]L. P. & T. R'y, '93; Ass't Eng. P. & St. L. R'y, '96-'97; Ma- [illegible] Inspector, S. L. P. & N. R'y, '98; Ass't Eng. St. R. & S. Elec. [illegible]'98; Ass't City Engr. '98 to date.
1937 St. Louis Ave., E. St. Louis Ill.

[illegible]ERTUS PARROTT, '86 B. S. (E. E.). Principal High School.
St. Johns, Mich.

[illegible]EFFERSON PARSHALL, '71 C. E. Chief Clerk State Board Land [illegible]rs.
Cheyenne, Wyoming.

[illegible]RA PARSONS, '75 C. E. Supt. Schools, Huron, O., '76-'80; Min- [illegible]ral Mineral Surveyor, '80-'83; Const'n Engr., Pacific Cable [illegible]'n Co., '83-'90; Civil Engr. San Francisco, Cal.

[illegible]ANDREW PASSOLT, '95 B. S. (E. E.). Asst. to Prof. Carhart, [illegible]6; Electrician with Field & Hinchman, Detroit, '96; do. Bart- [illegible]Dunn Co., Saginaw, '96-'97; do. U. of M., '97; Supt. Elec. [illegible] Co., '98 to date. Columbus, Miss.

[illegible]LIAM PAYNE, '83 B. S. (C. E.). U. S. Asst. Engr., Miss. River [illegible]t., '83-'94; In Business, '84-'92; Asst. City Engr., '92 to date.
128 Beet Ave., Akron, O.

[illegible]RY PEASE, '88 B. S. (C. E.). Instr. Math., Chgo., '88-'89; [illegible]ghtsman Toledo Bridge Co., '90; do. Detroit Bridge & Iron Wks. Detroit, Mich.

[illegible]LACKBURN PELHAM, '87 B. S. (C. E.). Asst. Engr. M. C. R. R. Died at Detroit, Feb. 2, '95.

[illegible]UMBOLDT PENNINGTON, '71 C. E. Surveyor and Farmer. Died [illegible]ison, Mich., Feb. 17, '90.

[illegible]ILLIAM PERKINS, '73 C. E. Chief Draughtsman Building De- [illegible]ent A. T. & S. F. Ry., '87-'89; Architect Topeka, Kan., '89-'90; [illegible] State Architect Kan., '92-'94; Architect City of Mexico, '96 to No. 20 Calle Mina Mexico, Mex.

[illegible]ERRIEN, '97 B. S. (Mech. E.), B. S. (Mich. Agr. Coll.).
440 Brush St., Detroit, Mich.

* Clarence Herbert Perry, '95 B. S. (C. E.). Engr. Corps., Chicago N. Side R. R. Died at Chicago, March 11, 1896.

Elliot Davis Perry, '71 C. E. Salt Lake City, Utah.

Ernest Blackman Perry, '89 B. S. (Mech. E.), '96 Mech. E. Superintendent Industrial Works, Bay City.
620 Grant Place, Bay City, Mich.

Thomas Osborne Perry, '69 A. B., '72 C. E., M. E., A. M. Engr. U. S. Wind & Pump Co. and Eclipse Wind Eng. Co., '76–'83; Airmotor Co., Chicago, '87; Inventor and Manufacturer. 1025 Park Ave., Chicago, Ill.

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Philetus Harvey Philbrick, '68 B. S., C. E., '73 M. S. Asst. Engr. J. Ft. W. & C. R. R., '68–'69; Chief Engr. T. A. A. & N. M. R. R. and Owosso & N. W. R. R., '69–'70; Res. Engr. Mich. Air Line, '70–'71; do. J. L. & S. R. R., '72; Prof. Civ. Engr. Iowa Univ., '73–'87; City Eng. Iowa City; Consult. Engr. State Capitol; Chief. Engr. K. C. W. & G. R. R., '87–'98: Chief. Engr. N. Am. Land & Timber Co. Lake Charles, La.

Lewellyn Sherrill Pomeroy, '93 B. S. (C. E.). U. S. Sub Inspector Masonry, St. Marys Falls, '92; Asst. Engineer Sewers, Dayton, '93; Instructor Mechan. Drawing, Kalamazoo Y. M. C. A., '96–'97; Farmer. Kalamazoo, Mich.

Irving Kane Pond, '79 C. E. With Pond & Pond, Architects.
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Chas. Poore, '68 C. E. Civil Engr. Western Springs, Ill.

Willard Pope, '88 B. S. (C. E.). Asst. Engr. Detroit Bridge & Iron Works.
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Minott E. Porter, '93 B. S. (C. E.), '98 C. E. Sub Inspector on U. S. 800 foot Lock at Sault Ste. Marie, '92; Draughtsman Sears Typo Matrix Co., Cleveland, O., '94; Computer U. S. Hydrographic Office, '94–'97; Computer U. S. Naval Observatory, '97 to date..
Naval Observatory, Washington, D. C.

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1124 Huron St., Toledo, O.

Chas. Pratt, '71 C. E., '76 A. M. (Madison Univ.), '81 M. D. (Jefferson Med. Coll.). Asst. Engr. U. S. Lake Survey, '73–'79; do. U. S. Rivers and Harbors, '79–'82; Physician. Fall Brook, Cal.

Chas. Alpheus Pratt, '93 (Non Grad.). Asst. Engr. Sperry Elect. Mining Mach. Co., '91–'92; do. Independent Elect. Co., '93; do. Link Belt Mchy. Co., '94–'96; Consulting Elect. Engr.
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George Charles Pratt, '97 B. S. (E. E.). Supt. Barrington Electric Light Co., '97–'98; Audit. Dept. Western Electric Co., '98; Mgr. do. '97 to date. LaGrange, Ill.

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Alfred Noble, '70 C. E., '95 hon. LL.D., M. Am. Soc. C. E. U. S. Asst. Engr. charge St. Mary's Falls Canal and St. Mary's River, '70-'82; General Supt. dr., '81-'82; Resident Engineer Shreveport Bridge, '82-'83; General Asst. Engr. N. P. R. R., '82-'86; Res. Engr. Washington Bridge, '86-'87; dr. Cairo Bridge, '87-'89; dr. Memphis Bridge, '89-'91; Asst. Chief. Engr. Bellefontaine, Afton and Leavenworth Bridges, '92-'94; Member Nicaragua Canal Commission, '95; dr. U. S. Board Engineers on Deep Water Ways, '97-'99; President Western Society Engineers, '98; Civil Engr.
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EDWARD BEEKMAN OLNEY, '86 (Non Grad.). In U. S. Weather Bureau up to 1893. Later on a ranch in California. Present whereabouts unknown.

FRANK BURT OLNEY, '91 (Non Grad.). With City Nat'l Gas Dept., Toledo, '91; member firm of Gov't Contractors of C. E. Mitchell & Co., '91; Dry Goods business. Ludington, Mich.

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*GEORGE EVERT PANTLIND, '75 C. E., '78 LL.B. Lumber Dealer, Grand Rapids, died in Chicago, March 23, '96.

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917 Chamber of Commerce, Detroit, Mich.

William Penn Parker, '94 B. S. (C. E.). Draughtsman Detroit Heating and Lighting Co.; do. Detroit Metal and Heating Co; Detroit Dry Dock Co.; Kenwood Bridge Co., Chicago; do. Whiting Foundry Co., Harvey, Ill.; do. Massillon Bridge Co.; do. Pittsburg Bridge Co.; do. Carnegie Steel Co., Ltd.; do. Keystone Bridge Works; Color Sergeant 1st U. S. Vol. Engineers. 4629 Fifth Ave, Pittsburg, Pa.

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James Franklin Park, '88 (Non-Grad.). Transitman, C. S. & St. L. R. R., '90; Rodman, C. St. L. & P. R. R., '87-'88; Levelman, M. R. & B. T. R. R., '89; Asst. Eng. American Association, Ltd., '90-'92; Chief Eng. W. Va. P. & T. R'y, '93; Asst. Eng. P. & St. L. R'y, '96-'97; Masonry Inspector, S. L. P. & N. R'y, '98; Asst. Eng. St. R. & S. Elec. R'y, '98; Asst. City Engr. '98 to date.
1957 St. Louis Ave., E. St. Louis Ill.

Lewis Meredith Parmoye, '96 B. S. (E. E.). Principal High School.
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Adrian Jefferson Parshall, '71 C. E. Chief Clerk State Board Land Com'rs.
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Edward Ira Parsons, '73 C. E. Supt. Schools, Huron, O., '76-'80; Mining and Mineral Surveyor, '80-'83; Const'g Engr., Pacific Cable Const'n Co., '82-'90; Civil Engr.
San Francisco, Cal.

Albert Andrew Passolt, '95 B. S. (E. E.). Asst. to Prof. Carhart, '95-'96; Electrician with Field & Hinchman, Detroit, '96; do. Bartlett Illum. Co., Saginaw, '96-'97; do. U. of M., '97; Supt. Elec. Light Co., '98 to date.
Columbus, Miss.

James William Payne, '82 B. S. (C. E.). U. S. Asst. Engr., Miss. River Improv., '85-'94; In Business, '94-'97; Asst. City Engr., '97 to date.
128 Bost Ave., Akron, O.

Wm. Henry Peabe, '89 B. S. (C. E.). Instr. Math., Chgo., '89-'93; Draughtsman Toledo Bridge Co., '93; do. Detroit Bridge & Iron Wks.
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Died at Detroit, Feb. 2, '98.

Elmer Hemenway Pendleton, '71 C. E. Surveyor and Farmer. Died at Mason, Mich., Feb. 17, '96.

Joseph William Perkins, '73 C. E. Chief Draughtsman Building Department A. T. & S. F. Ry., '87-'89; Architect Topeka, Kan., '89-'96; Asst. State Architect Kan., '92-'94; Architect City of Mexico, '96 to date.
No. 25 Calle Mina Mexico, Mex.

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440 Brush St., Detroit, Mich.

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HENRY CLAY RIPLEY, '70 C. E. U. S. Asst. Eng. Great Lakes & Gulf of Mexico, '70–'90; Civil & Hydrographic Engr., '90 to date. 2007 Fremont St., Galveston, Texas.

JOSEPH RIPLEY, '76 C. E. Surveyor Chippewa Co., '76; U. S. Inspector St. Mary's Falls, '77–'79; U. S. Asst. Engr. do. and St. Mary's River, '79–'97; do., in charge Survey, etc., Birmingham Canal, Ala., '97; General Supt. St. Mary's Falls Canal, '98–'99. 118 Portage Ave., Sault Ste. Marie, Mich.

WM. HARRISON RIPPEY, '97 B. S. (C. E.). Recorder U. S. Survey, Birmingham Canal, '97; Draughtsman Hardie-Tynes Co., Birmingham, '98; Asst. Engr., Birmingham Traction Co., '98; Draughtsman Keystone Bridge Wks, '99 to date. 349–44th St., Pittsburgh, Pa.

WM. BRADLEY RISING, '67 M. E., '64 A. B. (Hamilton Coll.), Ph. D. (Heidelberg); Prof Chemistry, Univ. of California. Berkeley, Cal.

WALTER ROBBINS, '96 B. S. (E. E.). Western Elec. Co., '96; F. B. Rae Eng. Co., '97; Pierce & Richardson, '97–'98; Western Elec. Co., '98 to date. Chicago, Ill.

FREDERIC COLEMAN ROBERTS, '97 B. S. (C. E.), B. S. (Earlham Coll.). With New State Teleph. Co., Detroit, '97–'98; Principal Schools, Greenbush, O. West Elkton, O.

OSCAR ROBERTS, '94 B. S. (C. E.). Missionary, Batanza, W. Africa. Box 2494, Johannesburg, S. Africa.

SETH ERASTUS ROBERTS, '95 B. S. (C. E.). Draughtsman King Bridge Co., Cleveland, '96–'97; do., Webster, Camp & Lane Mach. Co., Akron, '98; do., Detroit Bridge & Iron Wks., '99 to date. Detroit, Mich.

ALBERT ALONZO ROBINSON, '69 B. S. & C. E., '72 M. S., M. Am. Soc. C. E. Asst. Engr. St. Joe & D. C. R. R., '69–'70; do. A. T. & S. F. R. R., '71–'75; Chief. Engr. do., '75–'88; Supt. N. Mexico Division, '80; Asst. Gen. Supt. & Gen. Supt., '82; Chief Engr., '83; Second Vice Prest. and Chief Engr., '89–'93; Prest. Mexico Central R. R. 70 Kilby St., Boston, Mass.

STILLMAN WILLIAMS ROBINSON, '63 C. E., '96 D. Sc. (O. S. U.), M. Am. Soc. C. E., do. Am. Soc. Mech. E. U. S. Asst. Engr. Lake Survey, '63–'66; Asst. Prof. Min. Engr., U. of M., '66–'70; Prof. Mech. Engr. and Physics, Univ. of Ill., '70–'78; do. Ohio State Univ., '78–'95; Engr., Inventor and Expert; Consult. Engr. McKay Shoe Mach. Co. 1353 Highland Street, Columbus O.

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HUGH RODMAN, '93 B. S. (E. E.). Draughtsman Coast Survey of Alaska, '93–'96; With Alaska Mining Co., '96–'97; Gen'l Manager C. I. Mining Co., '97 to date. Point Breeze, Frankfort, Ky.

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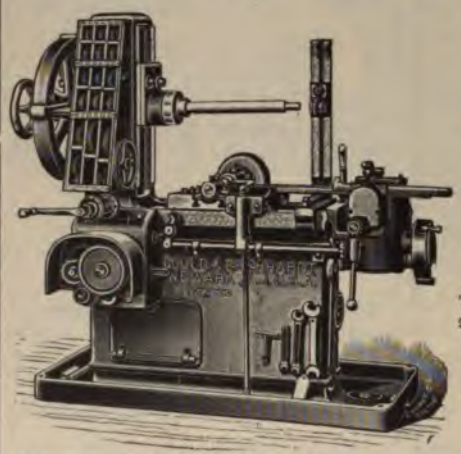

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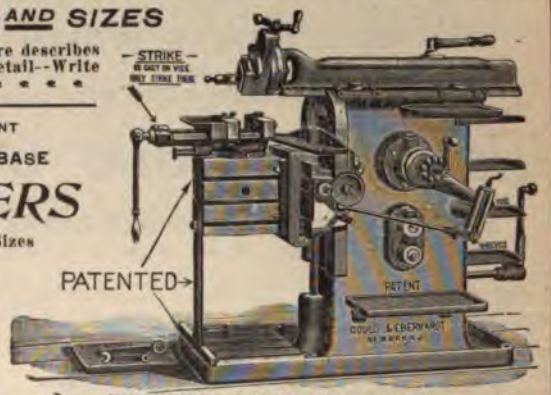


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1900

# THE TECHNIC

NEW SERIES NO 13

UNIVERSITY OF MICHIGAN ENGINEERING SOCIETY

CIVIL ENGINEERS IN THE U S NAVY.

carry on and properly supervise these various phases of its work, the Navy Department has established Bureaus. Thus, there are the Bureaus of Construction and Repair, Equipment, of Steam Engineering, of Navigation, of Medicine and Surgery, and of Supplies and Accounts, each intrusted with the class of work which its name implies. Many of the things coming under cognizance of each of these Bureaus are readily distinguished in a real or imaginary visit aboard any of the vessels belonging to our navy as they sail the high seas. But a day comes when each vessel must stop to replenish her supply of coal, of ammunition, of food, perhaps of men, and even the most perfectly made must often undergo repairs to her machinery, her equipment, or her gigantic, complex self. Her sides must be scraped and painted or perhaps repaired, her armament increased, or her armour thickened, and her frame strengthened to carry the added load.

In order to accomplish, to the best advantage, these and many other ends, the Government has established navy yards and naval stations upon the sea coasts of this country and her different possessions. There are at present along the sea board of the United States fourteen such yards and stations, and Cuba, Puerto Rico, Hawaii, Guam, the Samoan Islands, and the Philippines each have a naval rendezvous. Those on the home shores are at Portsmouth, N. H., Boston, New London, Conn., New York, Philadelphia, Washington, Norfolk, Port Royal, S. C., Key West, Dry Tortugas, Fla. ,Pensacola, Fla., Algiers, La., San Francisco and Puget Sound. Some of these places are especially equipped as coaling stations, such as the ones at New London,† Key West, Dry Tortugas, and the one on the Samoan Islands. Others have extensive docking facilities, such as the New York Yard with its three miles of water front lined with concrete or stone quay walls and its several dry docks, two now in use, one being reconstructed, and one under consideration with money appropriated by Congress for its construction.

Some yards are equipped principally with shops for repairs or construction work. The immense Government gun shops are located at the Washington Yard, and the New York Yard is so fully equipped that several men-of-war have been constructed upon the ways there. The Maine was launched from them not many months before her fatal trip to Cuba.

†For a description of this plant see Eng. News, Vol. XLIII., No. 3, p. 38, Jan. 18, 1900.

tenance of all docks (including dry docks), slips, wharves, piers, quay walls and buildings of all kinds, for whatever purpose needed, within the limits of navy yards, and naval stations * * * . It shall prepare the plans and make the estimates for the above structures.

(2) It shall repair and require for furniture for all buildings in navy yards.

(3) It shall be charged * * * with the purchase, sale and transfer of all land and buildings connected with navy yards, and shall also be charged with the care and preservation of all monuments of title to lands acquired for naval use.

(4) It shall provide light and water for all buildings, or for whatever purposes they may be needed in navy yards; and shall require for all fuel, except that which is used by other bureaus.

(5) It shall have charge of all landings, derricks, shears, cranes, sewers, dredging, railway tracks, cars, wheels, trucks, grading, paving, walks, shade trees, enclosure walls and fences, ditching, reservoirs, cisterns, fire engines and apparatus * * * .

(8) It shall determine upon and require for all the tools, stores, materials, means and appliances of every kind required for its own purposes, and erect and repair the same.

(9) It shall superintend all work done under it * * * .

(11) It shall estimate for, and defray from its own funds, the cost necessary to carry out its duties as above defined * * * .

(13) It shall have charge of the installation and maintenance of telephones within the limits of navy yards or stations."

It is immediately evident from this that the Government requires the services of men educated in that most conglomerate of all professions—Civil Engineering. The first civil engineer to do any extended work for the Navy Department was Laomi Baldwin, who, with several others, was employed in 1828 to consider the construction of the first dry docks. Thereafter, whenever thought necessary, the services of professional civil engineers were secured to carry on the various engineering enterprises required by the constantly increasing navy. On July 5, 1862, an act was passed by Congress whereby a civil engineer was to be constantly with the Bureau of Yards and Docks at the Navy Department in Washington, D. C. In 1867 Congress granted a civil engineer to each navy yard and station as was necessary to their welfare. At the beginning of 1872 eight such engi-

employed and in that year two more were appointed, the two being at the head of the list of civil engineers in the navy Rear Mordecai T Endicott now Chief of the Bureau of Yards and Captain Peter C Asserson, now in charge of the work at the Navy Yard

1871 the civil engineers were merely civil employees carried on rolls in the offices of the paymasters of the navy In 1871 Con ed an act providing relative rank for those holding civil engi ers but the President did not confer such rank until Feb 1881 There are at present twenty-six members in the corps having been limited by law in 1899

vacancies occur through death, resignation, retirement or authorized increase examinations are held of all those pre senting themselves Young men are eligible who are between the ages of and thirty-five who have graduated from a reputable engineer and who have had three years practical experience The examin tions have been rather tedious and exacting, covering gen ral education and experience The educational test covers Eng lish composition arithmetic algebra geometry, analytical geom try calculus both differential and integral theoretical me hydraulics geology mineralogy, engineering materials drawing, and mathematical specifications civil engineering strains in retaining walls dry docks marine railways sea walls, floating plants power plants water works, sewers railroads pave ments, wharves quays bridges electrical apparatus and methods, mines and water wheels pumps, etc

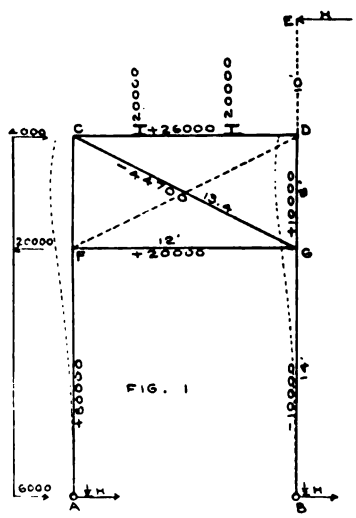
branch of engineering is delightful to the enthusiasts about but should all parts of its different phases present themselves never in rapid succession he cannot but be happy over his pro ct And this is the life of a Navy Civil Engineer

## PARTIALLY BRACED FRAMES:—PORTAL BRACING.

PROF. CHAS. E. GREENE.

The analysis of a trestle bent when the bracing extends only a portion of the distance from the top to the foundation is less simple than the discussion of ordinary frames, because bending moments are caused in the posts when a horizontal force, such as wind pressure or centrifugal force, is applied in the plane of the bent at or above its top. The same action takes place in the end or intermediate posts of a bridge, since the portal or other bracing occupies only the upper portion of the bridge cross-section.

The first case considered is represented by Figure 1. Here the posts are supposed to be practically hinged at the bottom, so that no moments exist at A and B; the inclined braces are ties. As the given external force H, at E, may act from either side, the two posts will be of the same cross-section, and hence will have the same stiffness to resist horizontal bending towards the positions shown by the dotted lines. Therefore the bending moments and shears will be alike in the two, and the horizontal components of the reaction at A and at B will be ½ H. The frame F C D G remains rectangular.

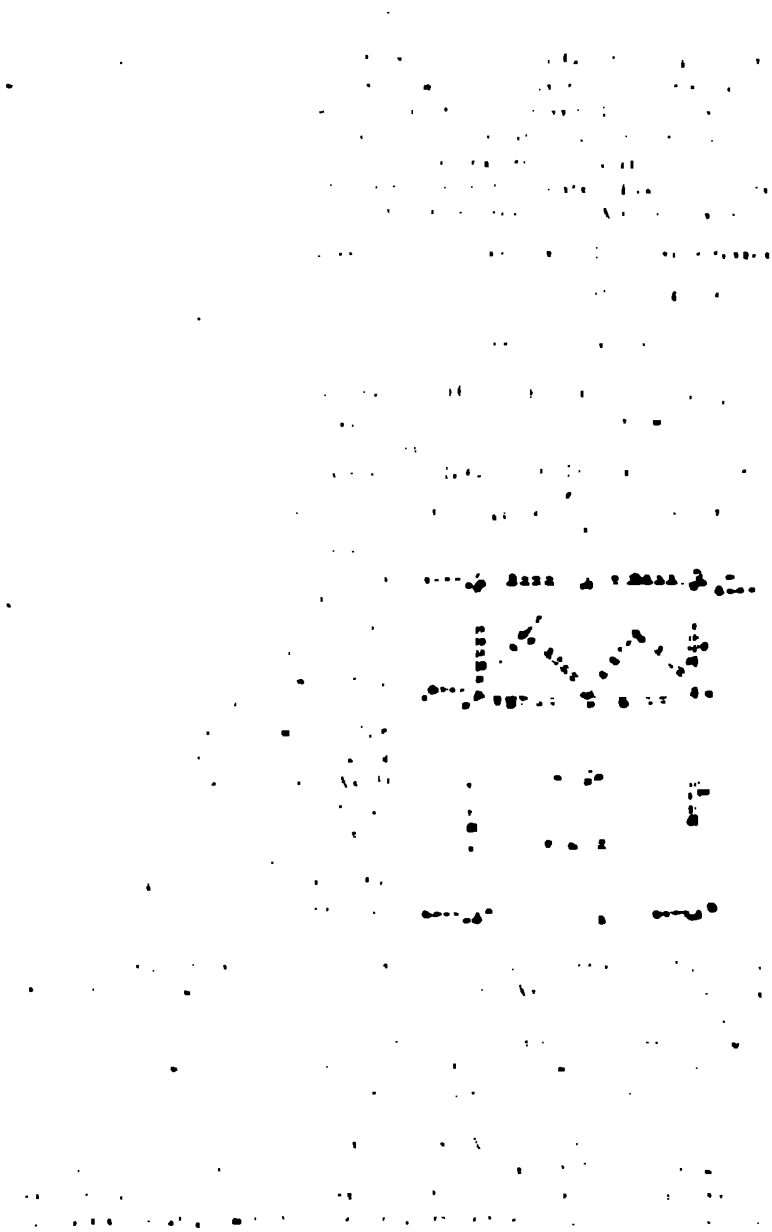



Let H = 12,000 lbs. and the size of the bent be as marked.

The bending moment M at F (or G) in the post, since there is no moment at A, will be ½ H × A F = 84,000 ft. lbs., which will call for a force at C to balance it with an arm C F. 84,000 ÷ 6 = 14,000 lbs. at C. The horizontal force at F will be equal and opposite to the sum of those at top and bottom, or 20,000 lbs. This force must be the thrust of the piece F G.

As the horizontal component of the tension in C G must supply this thrust in F G and must also exert an equal force on the post B D at G, the horizontal component of tension in C G = 40,000 lbs. and the tension itself = 40,000 × C G ÷ F G = $40{,}000 \frac{13.4}{12} = 44{,}700$ lbs.

(NOTE.—In Figure 1 the force at C should be 14,000, not 4,000 The dotted line should be the same as the one below $P_3$ in Figure 7.—ED.)



also be 9,000 lbs. The tensions and compressions in the diagonals will be 9,000 × 1.414 = 12,700 lbs.

As C K supplies 9,000 lbs. horizontal tension at C, and 12,000 lbs. is needed there, shown by the dotted arrow, to balance the 6,000 lbs. reaction at A, as explained in the case of Figure 1, C L must supply the remainder, or 3,000 lbs. tension as marked. At L, as indicated by the arrows below K, F L brings 9,000 lbs. of horizontal thrust and L G 9,000 lbs. of horizontal tension; hence, for equilibrium, L D must have 15,000 lbs. compression. This compression at D, to which is added 9,000 lbs. of horizontal component in K D, is balanced by 24,000 lbs., made up of 12,000 lbs. external force, and 12,000 lbs. reaction or shear which the post D B requires as it resists the external force.

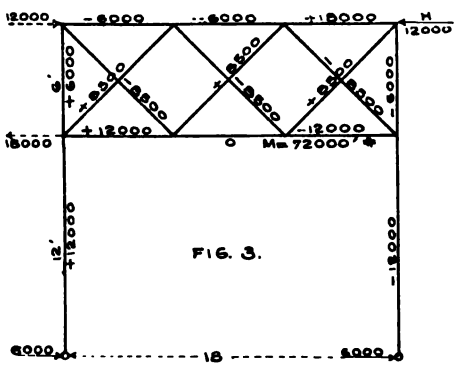


FIG. 3.

The same analysis gives the stresses marked on the lower horizontal member.

One must not be satified with the moments and stresses obtained unless they give equilibrium and thus check at all points.

A similar case will be the employment of three panels of 45° bracing, as shown in Figure 3. Note that the stress in the middle panel of the lower horizontal member is zero; and, as the two diagonals in each panel balance in stress, the top and bottom members in each panel give a resultant stress of + 6,000 lbs., being the half of H that must be transferred to the left post.

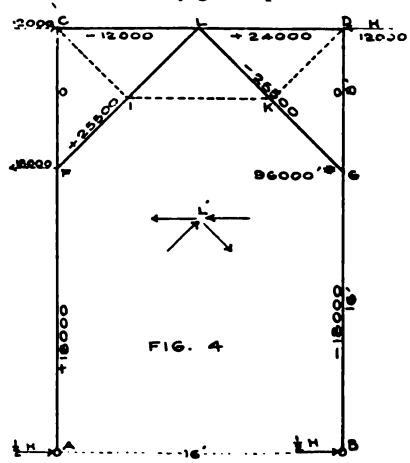
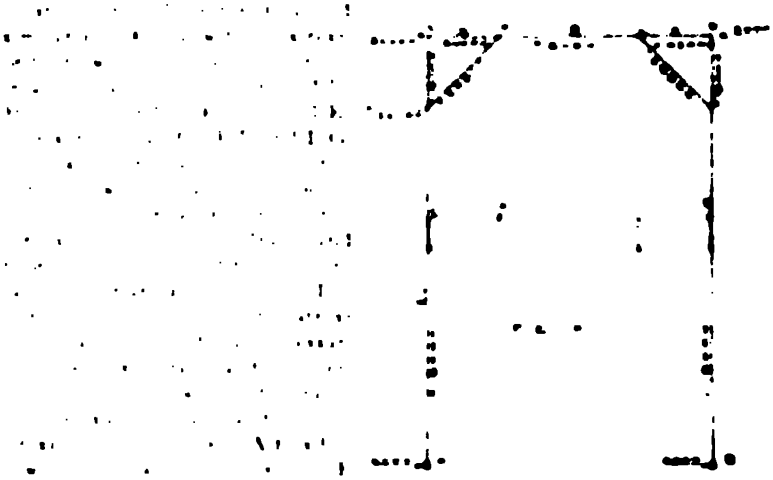


FIG. 4

If two knee braces, F L and L G are employed, Figure 4, the proportions of the frame being as indicated, the horizontal force at F and G is 18,000 lbs., which will be the horizontal component in F L and L G. The stress in the upper segment of the post becomes zero, and the stresses in the horizontal member are as marked.

A modification of this frame, shown by the addition of the dotted mem-



angle be denoted by M. The true diagram, when the post is fixed and restrained at A, is the shaded area, the bending moment at A being O N = $M_0$, and at F being P Q = $M_1$.

Let N S = $a$ and S R = $c$. Then the deflection F F′ from the tangent at A is proportional to

Triangle N P S · $\frac{2}{3}a$ — (Triangle O N Q · $\frac{2}{3}a$ + Triangle N Q S · $\frac{1}{3}a$) =

$$M \cdot \tfrac{1}{2}a \cdot \tfrac{1}{3}a - M_0 \cdot \tfrac{1}{2}a \cdot \tfrac{2}{3}a - M_0\frac{c}{a+c} \cdot \tfrac{1}{2}a \cdot \tfrac{1}{3}a.$$

Deflection C C′ is proportional to

Triangle N P R. vert. dist. from center of gravity to R — Triangle O N R · $\frac{2}{3}(a+c)$ = $M \cdot \frac{1}{2}(a+c) \cdot \frac{2}{3} \cdot \frac{1}{3}(c+a+c) - M_0 \cdot \frac{1}{2}(a+c)\frac{2}{3}(a+c)$.

Equate and reduce.

$$M_0 = M\,\frac{3a^2+5ac+2c^2}{3a^2+6ac+2c^2}.$$

This fraction is very nearly unity. The remaining moment P Q at F is

$$M_1 = M - M_0\frac{c}{a+c}$$

$$= M\,\frac{3a(a+c)}{3a^2+6ac+2c^2}.$$

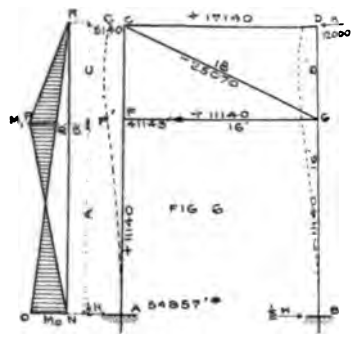
Since the bending moment at F must equal the moment at A plus the shear ($\frac{1}{2}$ H) at A multiplied by A F, $M_1 = -M_0 + \frac{1}{2}Ha$. Hence

$$M = \tfrac{1}{2}Ha \cdot \frac{3a^2+6ac+2c^2}{6a^2+8ac+2c^2}$$

$$= \tfrac{1}{2}Ha \cdot \frac{3a(a+2c)+2c^2}{(3a+c)(a+c)};$$

$$M_0 = \tfrac{1}{2}Ha \cdot \frac{a(3a+5c)+2c^2}{(3a+c)(a+c)};$$

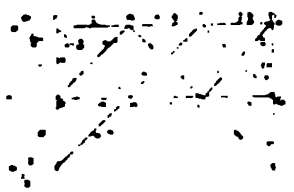
$$M_1 = \tfrac{1}{2}Ha \cdot \frac{3a}{3a+c}.$$




If the dimensions of the frame are as marked on the sketch, and H = 12,000 lbs., $M_0$ = 54,857 ft. lbs., and $M_1$ = 41,143 ft. lbs. Then the shear or horizontal force needed at the upper end C of the post is 41,143 ÷ 8 = 5,144 lbs., and the horizontal force supplied by the strut at F must be 6,000 + 5,144 = 11,144 lbs. The horizontal component in the diagonal tie will therefore be twice that amount, or 22,288 lbs., since the post at G must also be acted upon with the same force as at F. The tension in the tie itself will be 22,288 · $\frac{5}{4}$ = 25,070 lbs. The compression in the upper strut is 22,288 — 5,144 = 17,144 lbs.

The compression in A C is the vertical component of the stress in C G, or 22,288 · $\frac{4}{5}$ = 17,144 lbs. The tension in B G will be the same in amount. Any vertical load on C D will be carried by the two posts, as usual. The correctness of the stress in the posts, and hence of the other quantities, can be checked by moments about one of the points where the bending moment is zero; that is, at $M_0 \div H$ = 54,857 ÷ 6,000 = 9.14 ft. above A or B. Then 12,000(24 − 9.14) ÷ 16 = 11,145 lbs.

ame may also be braced at *three* points of attachment to each post, n Figure 7. This bracing is a combination of Figures 3 and 4. hree successive divisions of the posts, from the base up, be denoted d , and suppose at present that the posts are hinged at their ach post will tend to bend into the curve shown on the left, under a horizontal component of the reaction, H and the unknown forces $P_1$, $P_2$, and $P_3$, applied by the transverse bracing. The moment at $P_3$ is $P_3 a$, and at $P_2$ is $+ H a$, as marked



Suppose a tangent to be drawn to the curve at $P_1$. The equation of *areal moments*, for deflections of the spans and , at $P_1$ and $P_2$, from this tangent at $P_1$ will be

, or

$P_1$ $P_2$ $P_3$ A A —

H a A A A ,

$P_1$ $P_2$ H a A, or

$$P_1 = -H \frac{a A}{\frac{1}{2}(A + )}$$

Take moments below and about $P_2$, allowing the direction of $P_3$ to be determined by its sign.

H a A $P_3$ A $P_1$ ,

$$H \frac{a A}{\frac{1}{2}A + }$$

$$P_3 = -H\left( \frac{}{} + \frac{}{} \right)$$

moments above and about $P_2$.

$$P_1 = -H a \text{ or } H \frac{a}{} \quad P \quad H a$$

$$P_1 = -H a\left( \frac{1}{} + \frac{1}{2} \right)$$

$$P_1 = -H - P_1 - H$$

$$P_1 = \frac{H}{} - P_1 - H \frac{}{} P_3 = -H\left( 1 + \frac{3a}{2A} \right)$$

A, and P H , H as marked

etch H the , and vertical

nts of the stresses in the frame,

of H , the stresses in the

pieces, H

compression H H at the lower end

ntal component H , H at the vertical,

nt is also H which produces the stress in the next division of the to a tension of H . The upward thrust of the knee brace at K

must be resisted by C K and K S. R L and K S must have equal stresses of opposite kinds, as they bear similar relationships to the two sides of the frame. Further, the stress in R F must be equal and opposite to that in R L, to assure equilibrium in a vertical direction at R. Hence stress in F R = stress in K S. Let the vertical component of the stress in K C = $x$, and that in K S or F R = $y$. Then, in going up the post from F to C,

$$-1 - y + x = 0, \text{ or } y - x = -1.$$

At K, $y + x = 3$. $\therefore$ $x = 2, y = 1$.

The vertical component in K S is also one-half of the stress in the lowest part of the post. The stresses must check in each direction along the successive parts. Note that the stress in the middle division of the top strut is again $\frac{1}{2}$ H, and of the lower strut, zero, as in Figure 3.

If the frame carries a load, its effect can be added. If that load is applied at R and S, it will probably be transferred to the posts through the trapezoidal truss F R S G. If H is applied above D, the treatment is similar.

If $a = 3\,b$, $b = c$, distance between posts = $a$, and H = 12,000 lbs., the forces are,

$P_1 = 4{,}500$; $P_2 = 27{,}000$; $P_3 = 28{,}500$.

C R = $-$ 14,000; R S = + 6,000; S D = + 26,000.

F K = $-$ 37,000; K L = 0; L G = + 37,000.

C K = + 18,500 $\times$ 1.4; L D = $-$ 18,500 $\times$ 1.4.

Other diagonals = 10,000 $\times$ 1.4.

Knee-braces $\pm$ 28,500 $\times$ 1.4. Posts, 20,000 at bottom, 8,500 next, and 18,500 in F C and G D.

If the frame just treated has the posts firmly fixed in direction at their bases, the moment polygon for each post and the several horizontal forces applied to the post are represented, in Figure 8, at the left of the frame. With the same notation as before, let $M_3$ be first assumed as of the same sign with $M_2$ and $M_0$. The bending moment polygon will then be bounded by the dotted line, and the areas to be used will be more readily seen. The resulting values for M will have their proper signs.

It is evident that $M_2 = P_1\,c$.

The problem of the moments acting on the post, if the frame is rigid, is like that of a beam supported at three points in a straight line, and carrying no weight, but having one end fastened firmly in a wall at a point to one side of this line.

Area moments for spans $b$ and $c$ give, for deflections at $P_1$ and $P_3$ from the tangent at $P_2$,

$$-\tfrac{1}{3}\,M_2\,c^2 : \tfrac{1}{3}\,M_2\,b^2 + \tfrac{1}{3}\,M_3\,b^2 = c : b;$$

$$\text{or } M_3 = -2\,M_2\,\frac{b+c}{b} = -2\,P_1\,\frac{c}{b}(b+c). \qquad (1)$$

$M_3$ is also equal to $M_0 - \frac{1}{2}$ H $a$. $\therefore$ $M_0 + M_3 = \frac{1}{2}$ H $a + 2\,M_2$. (2)

As the tangent at A is vertical, the deflections of K and F from that tangent must be the same. The area moment equation will then be (left member for the point K, right member for F),

$M_1 = \dots$, $M_2 = \dots$ $M_3 = \dots + M_1 \dots + M_2 \dots + \frac{1}{2} M_3 A_3$.
$M_4 = M_3 \dots + \dots M_1 - M_2 \dots$

[illegible]

$$H = \dots M \dots \left( \dots M_1 \dots M_2 \dots \right) \dots$$

$$M_1 \dots H \dots \left( \dots \right)$$

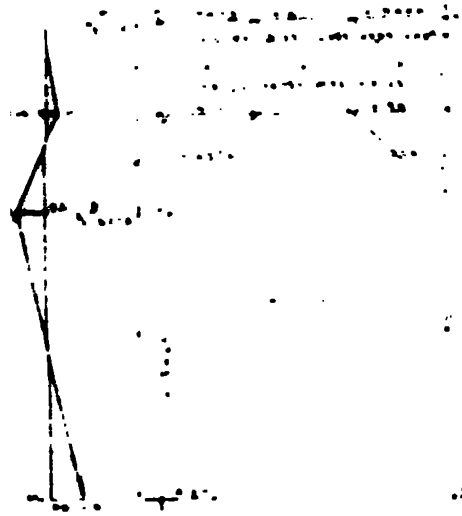
[illegible] and [illegible] from M and M

$M \dots \frac{1}{2} H \dots M \dots M_1 \dots H \dots \frac{1}{2} H$

$M \dots M_2 \dots \frac{1}{2} H \dots$

$\dots \frac{1}{2} H \dots M \dots P \dots \dots P_1$ or $P_2 \dots \frac{1}{2} H$.
$M_1 \dots \dots P_1 \dots \dots P_1$ or $P_2 \dots \frac{1}{2} H$
$P_1 = P \dots P \dots H$

[illegible] $P_1 \dots$ 12,000 lbs. $P_2 \dots$ 10,250 lbs.
$M_1 \dots$ 2,800.



The stresses of the width of the frame as [illegible] are marked on the sketch. The stress at the lower part of the post is found by taking the moment of H about the point where M is zero, which point may be [illegible] proportion from the moment [illegible] of the M [illegible] H. The [illegible] Then [illegible]

[illegible]

[illegible] of the [illegible] [illegible] [illegible]

The methods of determining the sizes of the several pieces and connecting parts, and of computing the section of a post subjected to transverse force, are treated in the writer's *Structural Mechanics*.

## DESIGNING A BOILER FOR SPECIAL CONDITIONS OF SERVICE.

FRANK M. DUNLAP, '85.

During the summer of 1899, the writer was called upon for an opinion in a case which finally involved the design of a boiler under conditions which made necessary a departure from the recognized methods of fixing its proportions by the horse-power to be developed.

In this article it is proposed to discuss the conditions governing the choice of the form of engine recommended, and the successive steps in the design of a boiler suitable for it. It is not intended to give computations in any other than a very general way, or to follow the design down to details.

A coal unloader, or machine for handling coal in car-loads from cars to vessel, at one of the Lake Erie ports had been in successful operation for several seasons, and was to be rebuilt on substantially the same lines, but increased in size to be capable of receiving cars of the largest size. The machine in question was of the type where a loaded car is run from an elevated track into a cylindrical steel frame, where it is secured by clamps, and the whole is rotated, by rolling the cage up an inclined track till the coal is poured out of the car into a chute leading to the hold of the vessel, when it is allowed to return by gravity to its first position where the empty car is released and pushed out by the entering loaded car.

It will be seen that the demands for power are short, very heavy, and at quite irregular intervals.

It was assumed, of course, that steam would be the motive power, but some uncertainty was felt as to the manner of its application. In the old machine steam was used in a horizontal, direct, single-acting cylinder, moving sheaves over which wire cables were reaved and carried around the periphery of the cylindrical cage so as to roll it on its inclined track.

On account of the large maximum, and comparatively small average, power demanded, it seemed as if some better mode of application of power

be made by considering the center of gravity of the whole to lie in the axis of rotation.

Now an elementary consideration of the balance of forces and the solution of a simple proportion give us a force of 90,000 (say 91,000) pounds, applied through the center, parallel to the inclined track, as the force required to maintain the load in equilibrium.

But it must be moved 23 feet 1 inch from rest back to rest again in six seconds, and its maximum velocity will be twice the mean, or such as would carry it 23 feet 1 inch in three seconds.

The force of gravity acting freely on a body for three seconds will produce a velocity of 96.6 feet per second; and to produce in three seconds, in a body which is in equilibrium under external forces, a velocity of 7.69 feet per second, we must add a force in the direction of the desired motion which is to the weight of the body (or force of gravity) as the desired velocity is to that produced by gravity. This calls for an accelerating force of 23,882 (say 24,000) pounds added to the 91,000 required to maintain euqilibrium.

There are additional resistances due to the stiffness of cables, rolling the load on the track, and friction of a pin rack placed beside the track and meshing in pin holes in the circumference of the cage.

These resistances, while not by any means negligible, are probably small in comparison with the other forces involved on account of the slowness of motion and size of the rolling cable. They are, moreover, so difficult to separate and estimate that any attempt to compute them would be of very doubtful value. As a good, fair, lump-sum allowance is to be preferred to an uncertain computation, which might give a false sense of security, we will allow for them and any other small resistances by adding 10,000 pounds to the combined supporting and accelerating forces, making 125,000 pounds in all, with the probability that the error, if any, is on the excess side. This force is to be applied through wire cables anchored in the framework, passing under and around the cage and over the head sheaves, down to the engine located in the lower part of the structure. The force to be applied to the cables will therefore be half of that computed from the center, and will operate through double the distance; that is, 62,500 pounds 46 feet 2 inches.

We are now in position to discuss the adaptability of the various forms of motor proposed for handling the machine.

om the foregoing the expenditure of power demanded is 62,500
at a rate of 4916 feet per minute (4916 ft. in 1-10 min.) = 874
verted for 1 to minute

the case of a car of lump coal the two rolls which succeed the first
more less power since approximately 100,000 pounds of the load has
scharged. Making a proportionate reduction, the next rolls call for
P. for 1 to minute each. Averaging these over 1½ minutes, we
equivalent of about 1460 H. P. used continuously. This is sufficiently
even on a half hour's run the cars are more apt to average 2 min-
an 1½ minutes apart; the latter being about the shortest interval
we should get thirty loaded cars of slack in half an hour, they would
ly require just 30 rolls each, and 874 × 1 to min. averaged for 1

874 H. P.

e difference between this and the 1460 H. P. above, will provide for
the latter cars as would require going up a second time to clear them out
om the fact that it offers us a choice between generating the power
spot and obtaining it from a commercial plant producing power on
scale, electricity would at first sight seem to be a very desirable
for the application of power. But, when we consider the great
m power called for and its short duration, the wiring from a com-
plant would be very heavy.

the electricity were generated on the spot, there would be required
generating plant equal to the maximum power required, and lying
ween times of a plant equal in capacity to the average requirement
P.) with a storage battery of great size and cost. In the case of the
there would be danger of damaging it by discharging so much
as undesirable.

875 H. P. motor car would be very expensive, and there are doubts
ther or not a large motor would stop and start quickly enough to be
e.

mpressed air on the contrary offers special facilities for storage of
for an engine of average power can run steadily compressing air
storage tank from which it can be used in large or small quantities
ed. It is also free from condensation which is the chief difficulty
am when used intermittently. But since the pressure of confined
proximately proportional to the amount compressed into a given
he pressure will vary as the air is drawn off for use. Now in order

to keep this variation within limits of pressure at which it can be used, we must either use exceedingly high pressure for storage and draw off for use through a regulating valve, or provide so large reservoir capacity that the amount drawn off at any time will be so small a portion of the total in storage that the pressure will not fall below workable limits.

The use of high pressure storage will involve increased expense for high pressure compressors, reservoirs and controlling valves, and a continuous expense for compressing to a pressure much higher than that at which it can be used; while the other alternative calls for a tank or reservoir so large that it may be objectionable on account of cost, or space occupied, or both.

Hydraulic pressure offers more advantages on some accounts than compressed air. It has the same facility of storage, the pumps for handling it are less expensive than air compressors, and it is, of course, equally free from condensation losses. The fluid is practically incompressible and therefore must be stored under a movable ram with weights to give it pressure. This fact affords us an advantage over compressed air in that the pressure remains sensibly constant till all that has been stored has been used. The incompressibility of the fluid has also one disadvantage in that as much power must be used for a light load as for a heavy one.

The availability of hydraulic pressure with accumulator storage, as well as of compressed air, will depend on the relation between mean and maximum power and the regularity of the intervals at which power is required. It will readily be seen that if two or more demands for maximum power are made at intervals so short that the prime mover has not had time to restore under pressure the fluid drawn off, we must have storage capacity under pressure sufficient to supply the necessary demands and permit the pumps to overtake the demand during succeeding longer intervals.

In order to inquire into the question of storage capacity, let us assume the use of a pressure well within the range of good practice, say 2,000 pounds per square inch. We require a pull of 62,500 pounds travelling 46 feet 2 inches; or, by reaving the cables so as to multiply the motion of the piston two, or four, fold, we may use a piston effort of 125,000 pounds through 23 feet 1 inch, or 250,000 pounds through 11 feet 6½ inches. Using the latter for the sake of compactness, we have a piston area of 125 square inches, which, travelling 138½ inches, sweeps 17,312.5 cubic inches at each

the old machine, cylinder condensation was one of the chief difficulties and sources of loss. But there the cylinder was only fairly lagged with non-conducting covering, and, being single-acting, the rear or outboard end was left open so that the air was freely drawn in and driven out at each stroke, thus carrying away a large portion of the heat of the cylinder walls during the time that the piston stood still at the end of the stroke.

Cylinder condensation cannot be avoided entirely in any cylinder acting intermittently, but it may be very much reduced by taking extra precautions with cylinder covering, making it double or triple thickness, with one or two dead air spaces between; and, in a single-acting cylinder, instead of leaving the end open, fitting it with an end or stopper which, while it would not seriously interfere with the passage of air to and from the cylinder, would act as a regenerator, taking up heat from the outgoing air and heating that which takes its place at the next stroke, so that less heat would be carried away from the cylinder walls. This might be made of any permanent and porous material as wire gauze or woven mats of loose asbestos cord, etc.

Steam, after being formed, can only be stored to a very limited extent and then only at the expense of adding external heat to repair losses by radiation, etc. But water may be used to a considerable extent as a medium for storing heat under favorable conditions, and the present case seems to present conditions which will enable us to use a body of water for that purpose and thereby simplify the plant to a very considerable degree.

We know that if a body of water under pressure is heated to a temperature corresponding to that pressure, and then the pressure lowered in any way, a portion of the water will be turned into steam. The heat which becomes latent in the process will be supplied by the body of water present, and will be sufficient in amount to form enough steam to restore equilibrium between a new pressure and its corresponding temperature, both of which will be slightly lower than the original if no heat has been added, or if insufficient heat has been added to make up for that drawn off in lowering the pressure. If heat has been applied during the process in quantity sufficient, or nearly sufficient, to make steam equal to that drawn off in the same time, then, if the demand for steam be stopped suddenly, the pressure will rise to or above the original and may become dangerous.

If we so proportion a boiler that the furnaces, grates, tubes, etc., are

d for supplying t the water heat at a rate equal to the average
d for power and containing a body of water sufficient to supply,
t too great a fall of temperature, the heat necessarily becoming
in supplying steam enough for two or three successive rolls of the
we will have secured our power storage in a manner to permit its
a to the work direct without the use of intermediate machinery
ing due to the greater simplicity of the machinery avoiding
d wear, charges and transfers of power, as well as the less
al and maintenance accounts and the slower depreciation, will
many times the cost of any losses due to unavoidable condensation

we propose in the strength of our boiler for a maximum press
pounds per square inch and take a cylinder of sufficient area to
with a pressure of 175 or 180 pounds we may draw steam from
quantities and the accumulated heat in the water
are exhausted the demand over the supply furnished by the fire
the
This may be repeated, each time at a slightly
pressure
enough can be permitted for the furnace to
demand or until the pressure falls too low to be
e

same
which led to the election of the short cylin
the
of the cables for the hydraulic system will
the
same scale for the use of steam direct with the
the short large cylinder will reduce the area of
compared with a longer small one and thus
radiation and condensation

shown
engage
we will require a pull of
strength
through 21 feet 1 inch or
the
Assuming the latter we find that for
steam pressure
pounds per square inch the area of the
cylinder
square inches nearly or
inches diam
We may
over
cleaves
end of the cylin
and
passing the
cables around the
length
long
inches
we may
have
suppose
the
cleaves
ing the
This
feet
tension
cables would be needed but the pressure on
would contained less thrown onto the framed structure when the rod

is in compression. There is also a slight difference in compactness in favor of the latter. The advantages are about even, and we will assume that the position with the rod in tension has been chosen.

If we could develop its full strength in fastenings, etc., we could use smaller, but probably about a 5½-inch rod will be used in such a cylinder. And since it passes through the steam space we must increase the area of our cylinder by 23.75 (say 25) square inches to compensate for it, giving a gross area of 1,414 square inches, nearly 42½ inches diameter.

The net stroke (or ¼ travel of pulling cable) will be 11 feet 6½ inches.

The fact that the accelerating force allowed for can act only in the first half of the stroke will permit us to economize fuel and reduce the capacity of the boiler by cutting off steam before the end of the stroke. The force required at the end of the stroke is only sufficient to maintain the equilibrium of the cage and empty car, which, as we have seen, is only about two-thirds of the similar force for full load, or 60,600 pounds; reduced to the piston, 121,000 pounds. This is so nearly half of the starting force that we may safely figure on cutting off at 54% of stroke, or say 6 feet 3 inches.

The amount of steam to be furnished at working pressure by the boiler for each stroke will therefore be (1,395 sq. ins. net area 9.69 sq. ft.) 9.69 square feet × 6.25 ft. = 60.56 cubic feet, or, per cycle of 1½ minutes, 181.68 cubic feet at 180 pounds pressure. This will require the evaporation of 181.68 × .433 = 78.67 pounds of water, or at a rate of 3,147 pounds per hour.

Since it is desirable to use the small sizes, or slack, of Ohio or Western Pennsylvania coal, we may assume an evaporation of 7 pounds of water per pound of coal, with feed water taken at ordinary temperatures from the city mains.

The average theoretical heat value of seven representative kinds of Ohio coal is equivalent to the evaporation of 14.41 pounds of water from and at 212° F. This equals about 11.63 pounds from 32° into steam at 180 pounds gauge pressure. A boiler efficiency of 60% to 70% reduces this again to from 7 to 8.14 pounds, from which 7 pounds seems reasonable for slack or three-fourths coal.

3,147 pounds of water at 7 pounds requires 450 pounds of coal per hour. Now since a slow uniform rate of combustion is desirable for heat storage we will assume a rate of 15 pounds per square foot of grate per hour.

in which it is to be used. The difficulty of getting foundations for settings, etc., will sometimes determine the use of brick settings or internal firing, and the requirement of large water space and broad disengaging surface practically limit us to some type of shell boiler. And since in this case the boiler must be placed on a pier or dock, it is probable that a boiler of the cylindrical marine, or Scotch, type will fulfill as many of the conditions as any.

Since the length of grate is limited in any case to five or six feet by the difficulty of firing, we must, in order to get 30 square feet, use two furnace flues 30 inches diameter inside. This will make the length of grate 6 feet.

If we use the corrugated flues which are usual in this style of boiler their outside diameter will be about 2 feet 10 inches.

In order to have ample water and steam space, let us try a shell 9 feet in diameter inside of outer plates, and by the use of extra large flange radii so place furnace flues, tubes, etc., that the minimum water space between them and the shell, and up through the center, shall be six inches.

Using a separate combustion chamber or back connection for each furnace and placing 26 4-inch tubes in each, we can get a spacing of 5 inches, centers vertically, and 6 inches, centers horizontally.

Since the combustion is intended to be slow, the heat required to produce draft will not be great, and we will expose to the water as large heating surface as can be obtained without unduly increasing the size of the boiler, say 30 square feet per square foot of grate, or 900 square feet in all. This is as great as in marine boilers of this type where the consumption of coal per square foot of grate is much higher.

If we make the combustion chambers 2 feet long, front to back inside, each presents a heating surface of 47 square feet, leaving 403 to be obtained in flue and tubes for each furnace. The flue, with a mean diameter of 2 feet 8 inches, exposes 8.35 square feet, and the 26 tubes 26 square feet per foot of length. $403 \div 34.4$ requires 11.71 feet, say 11 feet 9 inches length of flues and tubes. This gives tubes rather short for their diameter and their efficiency as heating surface would probably be increased by using spiral retarders in them.

With 6 inches water space between the combustion chamber and back head, this fixes the length of the boiler at 14 feet 6 inches, which allows 3 inches to be distributed where needed when deciding on details, thickness of plates, etc.

When carrying the water line 3 inches above the combustion chambers we have 20.6 square feet of section in the steam room, which multiplied by 14 feet 6 inches gives 299 cubic feet of steam room.

The volume of a 9 feet by 14 feet 6 inches cylinder, less 299 cubic feet and the volume of flues, tubes, and combustion chambers, gives 367 cubic feet water space. This is 1.8 times the computed amount necessary, though half as much as could be desired for regulating over long periods, but since it satisfies the conditions we have laid down as necessary, and the relative volumes of steam room and water space can be altered to a considerable extent by changing the water level, we will leave the fluctuations of longer periods to be cared for by manipulating the fires.

By the use of a small steam dome to give the steam outlet sufficient height above the water level the water could be carried even a foot higher, reducing the steam room and increasing the water space by about 122 cubic feet each. Still leaving the steam room equal to about three cylinders and making the water 489 cubic feet, or about 2½ times the computed amount.

Other ways in making use of heat storage in the water, special attention must be given to preventing loss of heat by radiation from the boiler, and herein lies one of the disadvantages of the type of boiler chosen, for, being enclosed in the brick walls of a setting, it must be covered with non-conducting material for that purpose solely. It is probable that a covering made of 1½ or 2 inches of plastic asbestos or magnesia compound with wire netting spaced out to form an inch of closed air space covered with an inch or more of hair felt and a metal or canvas jacket would prove thoroughly effective.

We have now followed the case through all the considerations which determined the choice of a motor, and have worked out the elements of a boiler suitable to supply steam to that motor by storing the excess of heat from a moderate fire during periods of inaction and giving it out as needed for short periods of heavy demand for power.

We have determined on a boiler of the Scotch marine type with moderate grate surface, slow combustion, large ratio of heating to grate surface, large steam room, and a large body of water for heat storage.

The remainder of the design presents nothing but the usual details of strength of materials and arrangement of covered joints, and we need not follow through them.

## TRANSIT ADJUSTMENTS AND TESTS.

J. B. DAVIS, '68.

### 1. PLATE LEVELS.

**a. REM.** If found much out, partially adjust the worse one first.

**b. DIR.**

**Preparation.**—Set up the transit firmly and level it carefully.

**Test**—Reverse the transit about its spindle. See if the bubbles read level. Reverse the transit back to its first position. See if the bubbles again read level. Repeat these trials, making the necessary corrections in the setting, or levelling, of the transit, till the bubbles will surely read level again when the transit is returned to its first position. Then reverse the transit, as at first, and note the deviations of the bubbles from level readings.

**Correct,** by estimation, one-half the deviation of a bubble by means of the screws that fasten the level tube to the plate

Level the transit carefully again. Test the adjustment as at first. Repeat the corrections and tests, in this manner, till no deviation appears when the test is made.

**c. Rem.** Check screws upon the adjusting screws of the level tubee (sometimes placed in the end plugs of the level tubes) must be released before making the correction. These check screws keep the level tubes longer in adjustment, but may give annoyance in making the adjustment Do not screw them too tight. Test the adjustment and see that it is correct after the screws are set.

The vernier plate and the limb plate may not be parallel in their motions. This may be tested by first adjusting the plate levels about the spindle with the plates clamped; then releasing the plates and clamping the spindle: and finally testing the adjustment of the plate levels about the axis of the vernier plate. If found out of adjustment with respect to the motion of the vernier plate, after carefully repeated trials, it shows that ths two plates do not revolve about the same axis. Leave the plate levels in adjustment with respect to the spindle if the principal work is running straight lines, and reversion on the spindle. If reading angles is the principal work, leave the plate levels in adjustment with respect to the motion of the vernier plate. In case this defect is serious the transit should go to its maker and be recentered.

Should it be found impossible to adjust the plate levels, after repeated careful trials, about either axis of motion, it shows that axis of motion with with respect to which this difficulty exists, to be badly damaged. Usually the maker must fix it. Make this test after the transit has had a fall.

### 2. LINE OF SIGHT. CLOSED WYES.

**a. COND.** A place to set the transit in is needed where well-defined, fixed marks can be readily found on opposite sides of it at a distance away

... telescope will show them clearly. It is well to have the ... the same angular distance, above on one side and below on ... place chosen. The plate levels should be in adjust- ... reversions of the transit made about the axis they are ...

### 5 DIR

**Preparations.** Set up the transit firmly in a suitable place. Level it ... line of sight on a distant, well-defined, fixed mark ... telescope about the transit axis and find a similar mark in ... Turn the telescope back and see if the line of sight strikes ... Repeat these points ing, making the necessary corrections ... and reversing of the transit till the line of sight will surely ... mark again when the telescope is turned back.

**Test** ... use the necessary clamps and reverse the telescope about ... the transit if the levels show a slight disturbance. Set ... on the first mark. Reverse the telescope about the transit ... second mark is in apparent line. Turn the telescope ... first mark, as before, and, by the same means, make sure the ... strike the mark. Then reverse the telescope, as at first, ... on of the line of sight from the second mark.

**Correct** ... mation, one fourth of the deviation of the vertical cross ... the screws at right angles with it that hold the cross wire ... Whether the telescope shows objects right side ... screws as if to increase the apparent deviation. Loosen ... ing the desired movement before turning the other ... screws under a gentle, even, strain. If the deviation is ... pair of screws slightly, but have a care not to ... wire too much.

... of sight again upon the first mark, as at first. Repeat ... and test the adjustment as near where the first was ...

**REM.** This adjustment is required ... running straight lines. It contributes to the best ... and ... both optically, and in the ...

## 3 STRIDING LEVEL.

### a DIR. ADJUSTING.

**Preparation.** Set up the transit ... level. Bring the ... Place the feet of the ... Level the ... that it stands ...

**Test** Carefully ... ings, without ... tion. See if the ... making the necessary ... the striding level ...

returned to its first position. Then reverse the striding level as at first, and note the deviation of the bubble from a level reading.

**Correct,** by estimation, one-half of the deviation by means of the adjusting screw, or screws, at one end of the level tube, provided for a vertical adjustment.

Set the striding level, by means of the levelling screws of the transit, to read, and stand, level again. Test the adjustment as at first. Repeat the corrections and tests, in this manner, until no deviation is shown by the test.

**b. REM.** In making this adjustment stand the striding level vertically over the bearings. Do not incline it. If inclined it may show this adjustment apparently imperfect. This requires a second adjustment sidewise to bring the axis of the level tube into a plane parallel to the line of the points of support of the feet of the striding level.

**c. DIR. Adjusting sidewise.**

**Preparation.**—Make the last adjustment as perfect as practicable.

**Test.**—Incline the striding level slightly on its feet. Return it to its first position. See if the bubble again reads level. Incline it in the opposite direction about the same amount. Return it again to its first position. See if the bubble again reads level. Repeat these trials, making the necessary corrections in the setting or levelling of the transit, till the bubble will surely read level again when returned to its first position, and stand at the same reading when inclined. Then incline the striding level, as at first, and note the deviation of the bubble from a level reading. Incline it a like amount in the opposite direction and note the deviation.

**Correction.**—By means of the screws for a sidewise adjustment set the level tube so it will show the same deviation in the same direction for the same inclination either way from its vertical stand, when tested as above described.

**d. REM.** The bubble should read level in all three positions. If it does not the bore of the glass tube is not uniform, and it should be replaced by a perfect one at the first opportunity. In using such a striding level be very careful to stand it plumb on its feet.

This adjustment, and the preceding, need to be made alternately together when first the bubble tube is attached to its base.

If, for any reason, the bubble tube has to be disconnected from its base, loosen but one of the sidewise screws and notice how tight it is. Likewise, if there is a check screw to the vertical adjustment, leave it alone,—only unscrew the adjusting screw. When the bubble tube is again restored to its connections with its base it can be set almost in its proper place by bringing the loosened screws to their bearings again, and not require so much adjustment.

## 4. TRANSIT AXIS TRUNIONS. ROUNDNESS.

**a. DIR.**

**Preparation.**—Separate the transit axis from the telescope. Clean its trunions and their bearings in the wyes of the transit. Set up the transit

transit carefully.
leveling screw.
standing level on the
standing level carefully
and put it in adjust
that everything is

See if it reads
at may be needed
the standing level,
read level

rings
Notice if it is
back to its
again reads
operation, and
transit as

it has
position
in these

not to rod,
defect
read
read
was
it
it
it

returned to its first position. Then reverse the striding level as at first, and note the deviation of the bubble from a level reading.

**Correct,** by estimation, one-half of the deviation by means of the adjusting screw, or screws, at one end of the level tube, provided for a vertical adjustment.

Set the striding level, by means of the levelling screws of the transit, to read, and stand, level again. Test the adjustment as at first. Repeat the corrections and tests, in this manner, until no deviation is shown by the test.

**b. REM.** In making this adjustment stand the striding level vertically over the bearings. Do not incline it. If inclined it may show this adjustment apparently imperfect. This requires a second adjustment sidewise to bring the axis of the level tube into a plane parallel to the line of the points of support of the feet of the striding level.

**c. DIR. Adjusting sidewise.**

**Preparation.**—Make the last adjustment as perfect as practicable.

**Test.**—Incline the striding level slightly on its feet. Return it to its first position. See if the bubble again reads level. Incline it in the opposite direction about the same amount. Return it again to its first position. See if the bubble again reads level. Repeat these trials, making the necessary corrections in the setting or levelling of the transit, till the bubble will surely read level again when returned to its first position, and stand at the same reading when inclined. Then incline the striding level, as at first, and note the deviation of the bubble from a level reading. Incline it a like amount in the opposite direction and note the deviation.

**Correction.**—By means of the screws for a sidewise adjustment set the level tube so it will show the same deviation in the same direction for the same inclination either way from its vertical stand, when tested as above described.

**d. REM.** The bubble should read level in all three positions. If it does not the bore of the glass tube is not uniform, and it should be replaced by a perfect one at the first opportunity. In using such a striding level be very careful to stand it plumb on its feet.

This adjustment, and the preceding, need to be made alternately together when first the bubble tube is attached to its basé.

If, for any reason, the bubble tube has to be disconnected from its base, loosen but one of the sidewise screws and notice how tight it is. Likewise, if there is a check screw to the vertical adjustment, leave it alone,—only unscrew the adjusting screw. When the bubble tube is again restored to its connections with its base it can be set almost in its proper place by bringing the loosened screws to their bearings again, and not require so much adjustment.

## 4. TRANSIT AXIS TRUNIONS. ROUNDNESS.

**a. DIR.**

**Preparation.**—Separate the transit axis from the telescope. Clean its trunions and their bearings in the wyes of the transit. Set up the transit

REM

DIR

clean the trunions and their bearings in the wyes. Set up the transit firmly. Level it carefully. Clamp the spindle so the transit axis will stand over a levelling screw. Place the transit axis in its wye bearings. Stand the striding level on the transit axis with its feet on the trunions. Level the striding level, carefully, with the levelling screws of the transit. Reverse it and put it in adjustment. Level the striding level again as at first. See that everything is stable, and steady, so the striding level will stand level.

**Test.**—Set the striding level off. Lift out the transit axis carefully, reverse it, and replace it in the wyes without jar. Replace the striding level without reversing it. Notice if it still reads level. Remove it as before. Restore the transit axis to its first position without jar. Replace the striding level. See if it again reads level. Repeat these trials. Make sure of the stability of the apparatus and of the reading of the level when the transit axis is reversed.

**b. REM.** If the level does not read level when the transit axis is reversed it shows the trunions to be of different sizes. They must usually be fitted by the maker, but may be treated as noted in 4. This method tests for differences in size. Should a difference be shown, the trunions are not made with precision enough for the striding level, or the level is too sensitive for the transit.

Professor Durand's three-point calliper may be made to give still more delicate tests for roundness and differences in size.

Theoretically this test will show whether the two trunions have a common axis. Practically, this defect would have to be so large as to be a disgrace to shops of the present day, for it to appear. Trunions are turned to the same size, even when using the term size with rigid precision. That is, the trunions are so nearly of a size that if the tests appear to show a difference, that difference is quite likely due to the errors of the test (observation, apparatus, temperature, etc.), instead of to the difference in size of the trunions. Some very elaborate tests would seem to confirm this view.

A level bubble can be read with as much more precision, with a reading glass than without as the graduations of the plate can.

## 6. LEVELLING THE TRANSIT AXIS.

**a. DIR.** Set up the transit and level it carefully with the plate levels. Stand the striding level on the transit axis over a levelling screw. Level the striding level carefully with the levelling screws of the transit. Reverse it and put it in adjustment. Level the striding level as at first. See that everything is steady so the striding level will stand level. Turn the transit one-quarter round on its spindle axis and level the striding level again. Turn the transit back to its first position,—do not reverse it. Level the striding level. By repeated trials set the transit, by means of the levelling screws, so the striding level will stand level in either position of the transit. Test the striding level again for its adjustment. Repeat these operations till the striding level shows the transit axis to be level in both positions of the transit and itself is in adjustment at the final test.

## 5. TRANSIT AXIS TRUNIONS EQUAL SIZE

### a. DIR

**Preparations.**—Open the wye clips, take out the transit axis, and

**b. DIR.**

**Preparations.**—Set up the transit firmly near some high, well-defined, fixed mark, so that when the telescope shall be directed to it the elevation will be about 45°. Level the transit carefully, as above noted. Set the line of sight on the high mark. Read, or estimate, the angle of elevation. Direct the telescope at the same angle below the horizon, on the same side of the transit. Find, or fix, a mark in apparent line. Turn back to the upper mark and see if the line of sight again strikes it. Repeat the pointings at both marks, making the necessary corrections in the setting and leveling of the transit, and in the position of the lower mark, till sure the line of sight will strike both marks with the transit carefully levelled.

**Test.**—Release the necessary clamps. Reverse the telescope about both axes. Set the line of sight upon the upper mark. Notice if the transit is still level. If not it must be reset, the levels adjusted if need be, and the whole preparations repeated. Having made sure of the setting of the transit and the pointing of the line of sight, direct the telescope downwards, as before, and find, or fix, a second mark in apparent line, with the same care, and tests, used in locating the first mark. See if the two lower marks are the same, or in exact line. Leave the telescope so as to show this.

**Correction.** — Move the vertical cross wire over one-fourth of the apparent distance between these two lower marks, by raising, or lowering, one end of the transit axis, by the device provided.

Prepare for and make a test of the adjustment, as at first. Repeat these tests, corrections, and tests, till the test shows the lower marks in the same line. or as one.

**c. REM.** This adjustment sets the axes at right angles with each other. It, theoretically, enables one to measure correctly the angle between the vertical planes of lines having very different angles of elevation.

## 9. AXES. OPEN WYES.

**a. REM.** The axes may be adjusted in the way given for closed wyes in **8.** This process involves levelling the transit with the striding level independently of the adjustment of the axes, which adjustment is involved in the usual process of thus levelling the transit. If the striding level feet do not stand on the transit axis trunions, use the process for adjusting the axes given in **d** below. If the transit has a delicate level attached it may be levelled by that, according to the next paragraph, or according to **10, b.**

**b. DIR. Levelling with the Transit Axis Striding Level.** Set up the transit firmly and level it carefully with the plate levels. Place the striding level in position. Turn the transit on its spindle so the striding level will stand over a levelling screw. Level the striding level carefully with the levelling screws to the transit. Turn the transit one-quarter round and level the striding level again. Turn the transit back to its first position,—do not reverse it. Level the striding level again. Turn the transit to its second position,—do not reverse it. Level the striding level again.

...transit by means of its levelling screws so the ... one of these positions ...

... Notice the reading of the striding ... and see if the striding level now reads level. ... the necessary corrections in the setting or ... the striding level will certainly read level in ... the same reading always in the reversed ... reversed. Note the deviation of ... reading.

**Correct** ... the horizontal adjusting screw of the ...

... level, then the reversions, and ... in the setting of the strid- ... as before.

... striding level will read level in ... reversed.

... so it will read level when ... as before.

... striding level is set to read ... around on its spindle, or, ... stand level during a com- ...

**c RIM** ... The striding level will ... in this process. Any such ... and used to level the ... being provided with a ... instead of an adjusting screw as ... b.

**d DIR. For adjusting the Axes. First Method.**

**Preparations** ... defined, ... directed toward the eye- ... in b or in **10.b.** Set ... of the transit ... Direct the tele- ... same end of the trans- ... not, reverse upper ... work satisfactory. Then ... and see ... and over at the ... and the level, and ... end over the trun- ... of sight will ... this ... level.

**Test** ... Set the line of sight upon the upper mark. Notice if the tran- ... still level. If not, it must be reset and levelled as directed in b or in

**10, b.** Having made sure of the setting of the transit and the pointing of the line of sight, direct the telescope downwards as before, and find, or fix, a second mark in apparent line, with the same care, and tests, used in locating the first mark. See if the two lower marks are the same, or in exact line. Leave the telescope so as to show this.

**Correction.**—Move the vertical cross wire over one-fourth of the apparent distance between these two lower marks, by raising or lowering one end of the transit axis by the device provided.

Prepare for, and make a test of the adjustment, as at first. Repeat these tests, corrections, and tests, till the test shows the two lower marks in the same line, or as one.

**e. REM.** The process of **b, c** and **d,** will reveal defects of construction that can be shown by the striding level. For this reason the examinations noted in **4** and **5** should be the first made. The process in **b** will not show a difference in the size of the transit axis trunions.

**f. DIR. For Adjusting the Axes. Second Method.**

**Preparations.**—Set up the transit firmly and level it carefully with the plate levels. Place the striding level in position. Turn the transit on its spindle so the striding level will stand over a levelling screw. Level the striding level carefully with the levelling screws to the transit. Remove the striding level, reverse it, and replace it, as in adjusting it. See if it is much out of adjustment. If it is, adjust it approximately.

Level the striding level carefully with the levelling screws to the transit. Turn the transit one-quarter round and level the striding level again. Turn the transit back to its first position,—do not reverse it. Level the striding level again. Turn the transit to its second position,—do not reverse it. Level the striding level again. By repeated trials set the transit, by means of its levelling screws, so the striding level will read level in either of these positions.

Adjust the striding level by the process of **3, a** as perfectly as possible.

Level the transit again, as above directed. Test the adjustment of the striding level. Repeat these operations till sure the transit stands steady, the striding level is in nice adjustment, and that it reads level in either position of the transit.

**Test.**—Reverse the transit on its spindle. Notice the reading of the striding level. Reverse back again and see if the striding level still reads level. Repeat these reversions, making the necessary corrections in the setting, or levelling of the transit, or the adjustment of the striding level, till the bubble will certainly read level in the first position of the transit, and return to the same reading always in the reversed position. Leave the transit reversed. Note the deviation of the bubble of the striding level from a level reading.

Correct one half this deviation by raising, or lowering, one end of the transit axis, by the device provided.

Prepare for and make a test of the adjustment, as at first. Repeat these tests, corrections, and tests, till the test shows the striding level

[illegible]

[illegible] REM [illegible]

## [illegible] TELESCOPE LEVEL TUBE

[illegible]

DER For levelling the transit [illegible]

**Correct** one half of this deviation by the slow motion screw to the transit axis.

Level and reverse the transit again, as before.

Repeat these operations till the telescope level will read level in either the first, or the reversed position, of the transit.

Turn the transit one-quarter round and level it again, as above set forth.

By repeated trials, making the necessary corrections in the setting of the transit and the telescope level, as above directed, make this level read level for any position of the transit when turned on its spindle.

**c. DIR. For setting the line of sight level.** Level the transit as above directed. Leave the telescope clamped. Measure off, each way from the center of the transit, the same distance, say 150′ or 200′, and drive a stake till firm, at the end of each measurement. Number these stakes 1 and 2. See that the transit is level and stands steady. Take accurate rod readings on the tops of the stakes. Subtract the reading on 1 from the reading on 2 and preserve the sign of the result, + or —. Call this result k.

Move the transit to a place, a short distance, say 30′, beyond stake 1, carrying the telescope clamped as last used. Set up the transit here and level it as directed in b. Take a rod reading, $r_1$, on stake 1 and another, $r_2$, on stake 2, just as the first ones were taken. Record these with their numbers. Find $r_2 - r_1$, noting the sign. Call this k′. See if $k = k'$. Make sure of the whole work.

If $k = k'$ the line of sight is horizontal and the level tube in adjustment. If k′ does not equal k, measure the distances from the transit's center to stake 1, $d_1$, and to stake 2, $d_2$. Find a rod reading, $R_2$, for stake 2 by the following equation, observing all signs:

$$R_2 = r_2 + \frac{k - k'}{d_2 - d_1} d_2 \quad \ldots\ldots (1)$$

Hold up the rod on stake 2 (set at this reading, $R_2$, if a target rod), and by means of the slow motion screw to the transit axis, set the line of sight so it will give the rod reading, $R_2$, on stake 2.

**Test** by taking a new rod reading, $R_1$ on 1. Find $R_2 - R_1$, observing the sign of the rsesult. See if the result equals k.

Proceed with these trials and tests till the line of sight is set so that $R_2 - R_1$ at a test, equals k, or so near it that the experiments show it to be useless to try further.

**d. DIR. For setting the level tube.** Set the level tube to read level by means of the nuts at one end of it. Start that nut first that will permit the desired movement Leave the nuts under a gentle even strain.

**Test** the level tube adjustment by additional rod readings and finally set it so that $R_2 - R_1 = k$ when the bubble stands level,— or as near this condition as can be.

**e. REM.** If the ground is near enough level, drive the stakes so the

the rod readings on them will be equal. Then k = 0. Proceed as above directed after that, but use the equation below instead of (11), observing all signs

$$R_2 = r_2 \frac{k'd_2}{d_2 \quad d_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

With some experience in making this adjustment, probably the equations will be dispensed with.

f. **DIR. Double ground level tube.** Adjust as directed in b, c, d, and e above, using but one side. Release the necessary clamps, reverse the telescope about both axes, and set the line of sight horizontal by means of the rod readings on stakes 1 and 2. See if the bubble of the telescope level reads true. Repeat the observations and rod readings till sure the line of sight is level, the transit steady, and the bubble gives the same reading. Note the deviation of the bubble from a level reading.

Set the bubble to read level by means of the slow motion screw to the transit axis. Take a rod reading on stake 2, the distant stake.

Move the horizontal cross wire by means of the screws at right angles with those that hold the cross wires in the telescope tube, and set it so the rod reading on stake 2 will equal the half sum of the former rod readings on the stakes, the one when the line of sight was level, and the one when the bubble read level. Whether the telescope shows objects to right side or left, turn these screws as if to increase the apparent deviation of the second rod reading from the first. Loosen the screw permitting the desired movement before turning the other. Leave the screws under a gentle even strain. If the difference between the two rod readings is large loosen the other pair of screws slightly, but be very careful not to turn the cross wire ring. Be certain the transit stands steady and the rod readings are correct.

Set the line of sight again level by means of rod readings on both stakes.

Set the level tube to read level by means of the screws at one end of it. Move the rod first that will permit the desired movement. Leave the screws under a gentle, even strain.

Test the level tube adjustment by additional rod readings and turn it so that $R_2 - R_1 = k$ when the bubble stands level, or as near this condition as may be.

Release the necessary clamps, and reverse the telescope about both axes. Set the line of sight level by rod readings on both stakes. See if the bubble of the telescope now reads true. If not, bring it to the adjusted reading level. Repeat the observations and rod readings till sure the line of sight is level, the transit steady, and the bubble gives the same reading. Note the deviation of the bubble from a level reading.

If this is considerably less than before, [illegible] the bubble tube, make the same observations and adjustments for the first bubble as above detailed for the other.

Release the necessary clamps, [illegible]

and make the test just above noted, anew for the side of the bubble tube which is again uppermost.

Repeat these trials, adjustments, and tests, till the telescope level, and the horizontal cross wire, are so set that the line of sight will be level when the bubble reads level whichever side up the bubble tube may be, as shown by rod readings on both stakes.

If persistant trial under favorable conditions of light, seeing, temperature, and steadiness, does not complete these adjustments so they will bear the test imposed, or very nearly so, repeat the work and make these adjustments so the two sides of the bubble tube will read the same (not a level reading) when the line of sight is level. Record this reading, and fasten it in the transit box.

**g. REM.** By these last adjustments the horizontal cross wire is set nearer its proper place in the telescope tube, if not at that place. The trouble of these adjustments shows the value of such a level tube in such a place. Once the level tube is proven to be ground alike on both sides it makes matters somewhat easier. Even with a perfect level tube there can be no sidewise adjustment and the device is not nearly as perfect as that of a striding level standing on collars turned on the body tube of the telescope.

**h. DIR. Horizontal cross wire. Striding telescope level.**

**Preparations.**—Set up the transit firmly. Level it carefully with its plate levels. Clamp the spindle so the telescope will stand over a levelling screw. Clamp the telescope level,—as shown by its striding level. Adjust the striding level as directed in **3**. Level the transit by means of the telescope level as directed above in **b**. See, at the last, that the striding telescope level remains in adjustment with respect to its own feet.

Direct the telescope to some object and find a mark on it in line with the horizontal cross wire when the transit is carefully levelled by the telescope level, and that level is in good adjustment. Prove the steps and make sure the conditions are favolable.

**Test.**—Release the necessary clamps. Reverse the telescope about both axes, and set it level as before. Be sure the striding level keeps its adjusment. Note the deviation of the horizontal cross wire from the mark it covered before.

**Correction.**—Move the horizontal cross wire by means of the screws at right angles with it, that hold the cross wires in the telescope tube, and set it so it will cover a place midway between the two marks above noted, when the telescope is level.

Test the adjustment as at first. Repeat the test, correction, and test, till the horizontal cross wire will cover the same mark with the telescope either side up, and level.

**i. REM.** This arrangement of a telescope level is the best for general use. The same striding level may be made to fit the transit axis also.

## 11 VERTICAL CIRCLE VERNIER.

**a REM.** If the telescope is provided with a level, as shown in Fig. 10, the adjustment of the horizontal cross wire is described as follows: Set the vernier to the zero of sight and the horizontal cross wire to read zero when the line of sight is level. Then the vernier will read zero when the line of sight is level.

[illegible] have a vertical arc in the place of the [illegible] Some [illegible] the vernier to the zero of sight, and the horizontal cross wire to read zero when the line of sight is level. Then the vernier will read zero when the line of sight is level. With opposite [illegible] the vernier will read zero when the line of sight is level. The adjustment is made by taking a reading to the [illegible] and then reversing the telescope and taking a reading to the [illegible] The mean of the two readings will be the correct reading when the line of sight is level. The adjustment is made by taking a reading to the [illegible] and then reversing the telescope and taking a reading to the [illegible] The mean of the two readings will be the correct reading when the line of sight is level.

[illegible] the vernier to the zero of sight, and the horizontal cross wire to read zero when the line of sight is level. Then the vernier will read zero when the line of sight is level. With opposite [illegible] the vernier will read zero when the line of sight is level. The adjustment is made by taking a reading to the [illegible] and then reversing the telescope and taking a reading to the [illegible] The mean of the two readings will be the correct reading when the line of sight is level. The adjustment is made by taking a reading to the [illegible] and then reversing the telescope and taking a reading to the [illegible] The mean of the two readings will be the correct reading when the line of sight is level.

**b DIR Full vertical circle. Opposite verniers**

**Preparations.** [illegible] the vernier to the zero of sight, and the horizontal cross wire to read zero when the line of sight is level. Then the vernier will read zero when the line of sight is level. With opposite [illegible] the vernier will read zero when the line of sight is level. The adjustment is made by taking a reading to the [illegible] and then reversing the telescope and taking a reading to the [illegible] The mean of the two readings will be the correct reading when the line of sight is level.

**Test** [illegible] the vernier to the zero of sight, and the horizontal cross wire to read zero when the line of sight is level. Then the vernier will read zero when the line of sight is level. With opposite [illegible] the vernier will read zero when the line of sight is level. The adjustment is made by taking a reading to the [illegible] and then reversing the telescope and taking a reading to the [illegible] The mean of the two readings will be the correct reading when the line of sight is level.

**Correction.** Set the vernier to the zero of sight, and the horizontal cross wire to read zero when the line of sight is level. Then the vernier will read zero when the line of sight is level. With opposite [illegible] the vernier will read zero when the line of sight is level. The adjustment is made by taking a reading to the [illegible] and then reversing the telescope and taking a reading to the [illegible] The mean of the two readings will be the correct reading when the line of sight is level.

means of their slow motion screw, or such other device as is provided, to read 0° 00′ 00″ and 180° 0′ 00″, or one at 0° 00′ 00″, and record the readings of both. Fasten these last readings in the transit box.

Set the level to the verniers to read level, if there is one, after setting to read 0° 00′ 00″ and 180° 00′ 00″ as above.

Test the adjustment as at first. Repeat the preparations, tests, corrections, preparations, and tests, till the line of will strik the same mark which ever side up the telescope may be when the verniers are set for a level line of sight, and the transit carefully levelled, or as nearly as can be to these conditions.

## 12. LINE OF SIGHT.

If a transit has a telescope level attached to its body tube, it being in adjustment in respect to the line of sight, and it is necessary to adjust the vertical cross wire, as in **2**, some work may be saved by levelling the transit for that adjustment with the telescope level, setting the line of sight level, and observing some mark in line with the horizontal cross wire, before beginning the adjustment of the vertical wire. After the vertical wire is adjusted set the horizontal wire on the same mark, first seeing that the transit is as well levelled, as before, and adjust the telescope level to read level again, in case it need it.

It is especially easy to derange the cross wires whenever all four cross wire screws are loosened.

If the telescope level is a sliding level it is so little work to adjust the horizontal cross wire that it had better be done instead of depending on any such device as here given.

## 13. CENTERING THE EYE-PIECE.

**a. REM.** This is for the purpose of clear vision, as one might center a magnifying glass more carefully over an object to be viewed. Frequently there is no way provided for making this adjustment, and none is needed.

**b. DIR.** Set up the transit where the telescope can be directed to the light,—artificial lifght will do. By means of the four screws like, or similar, to the cross wire screws, that hold the ring in the body tube of the telscope, in which the inner end of the eye-piece slides, set that ring so the cross wires divide the field of symetrically.

## 14 THE OBJECTIVE SLIDE.

**a. REM.** No adjustment of the objective slide should be needed. At this point the skill of the maker should be manifest. A test is given below instead of an adjustment. This test will indicate how perfectly the slide is fitted, if the objective is well mounted, or how well the objective is mounted if the slide is well fitted. Two imperfections may be present, or but one of them. An adjustment does not correct the difficulty. It partly hides it.

**b. DIR.** [illegible] where a row of stakes can be lined by it with [illegible] except changing the focus of the objective. [illegible] with respect to all its motions. Line out a [illegible] of stakes at the regular intervals of fifty feet, to 1,000 or 1,500 feet away. [illegible] at the end of the line, or beyond it, to keep the [illegible] Mark points on these stakes precisely in line, and at [illegible]

[illegible] to the other end of the line and by trial set it so the [illegible] with no motion but focussing the objective. [illegible] Line a new set of points at the [illegible] Note [illegible] stations. There should be none.

[illegible] Another test with respect to level [illegible] of tall stakes in the line of the [illegible] The cross-hairs cross were cannot be easily set to [illegible] marks in the second position of the transit. Set the telescope [illegible] from one station now to the transit and so the line of [illegible] with [illegible] at equal distances from, and on [illegible] the end marks. Make a new set of marks. Measure [illegible] the former marks. They should be equal.

## AN IRRIGATION INVESTIGATION.

[illegible] Western Hemisphere [illegible] [illegible] [illegible]

cess of an irrigated country. In other countries where irrigation was practiced at an early date, land titles were comparatively definite and secure. We have nothing to tell us how the original builders of these canals governed the use of water; its division is a much more difficult task. Hence, the character of the right to use it is much more uncertain. Not only does it require engineering skill to measure the volume to be distributed, but owing to atmospheric changes at the sources of supply, this volume fluctuates. When we say a man or his farm is entitled to ten cubic feet of water per second we may be allowing him a quantity which at times does not exist. If he has an early or prior right to use water and yet has an inadequate supply, it is difficult to see where those having subordinate rights to his come in.

Notwithstanding the antiquity of irrigation, but little is known as to how much water is needed for the growth of crops under varying conditions. Although this quantity has long been known to differ with soil, latitude, altitude, character of crops, and even the quality of the water applied, yet no measurements have been made until recently which begin the solution of the various phases of the problem.

Nearly all disputes as to the ownership and use of water in Arid America have been settled by the courts. The courts have inaugurated no study as to the needs of the irrigator; they have treated water the same as land or personal property, without regarding the area it does or may serve to irrigate, but have given more weight to the claims of the irrigators and the carrying capacity of their ditches and canals. A student of the problems connected with the supply furnished by streams, and the judicious division of this supply among the various users, at once sees that they can only be solved by engineering skill.

A stream has a public nature which the courts have long ignored. The doctrine of holding water as personal property has resulted in sufficient litigation in some of the states to pay for all the irrigation works constructed therein. This has been avoided in Wyoming and Nebraska by putting the diversion and use of water under the charge of state engineers and boards controlled by them. All adjudications are made by men equipped for this particular work. When the rights to use water are to be established for any stream, the available water supply is determined and each user of water is allowed only what can be beneficially applied to the land.

This method of dealing with streams has practically eliminated all litiga-

Of course, there is no justice in a decision of this kind. It may be law, but it is bad practice, and certainly not engineering.

It cannot be denied but that practically all of the court decrees have been conscientiously rendered. The difficulty is that the courts do not appreciate, and are incompetent to judge, the value of the engineering facts which enter into every adjudication of the rights to use water. Every profession views a question according to the light afforded by special education and practice Hence, where an engineer would apportion the water of a

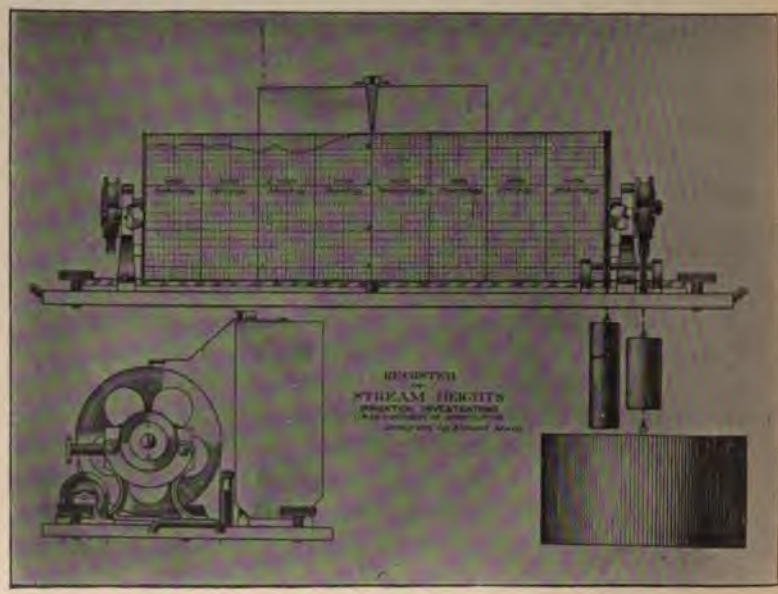


FIGURE I.

stream to all the users in accordance with the amount needed, and the area and date when first irrigated, the lawyer would adjudicate the rights of as many as appeared in court and fix the quantity decreed to each according to the facts presented by the irrigators, and a physician would probably diagnose the case and prescribe a course of treatment.

When water-right questions were first appealed to the courts but little was known as to the flow of the streams, the carrying capacity of the ditches, the area irrigated, and nothing was known as to the quantity of

fact. The court did not even appreciate the need of such facts to equitable adjudication. It is not surprising therefore, that practically every case appeared time and again in the courts, serving only to enrich the irrigation lawyer and to impoverish the irrigator who hires him.

The irrigator knows approximately how much water he uses for various purposes, but since he has made no measurements his information cannot be used. Hence, a judge or other person adjudicating the rights to the use of water in his locality cannot be aided by his knowledge. The want of facts such as these, as well as the absence of other information relative to irrigation, led to the establishment of the Irrigation Investigations under the Department of Agriculture. This office has started its search for truth in various channels, yet that relating to the duty of water is the most important. A brief review of this work will make clear the methods adopted. The first year's work deals with the measurement of water actually delivered to the land. One or more stations have been established in nearly every irrigated state and engineers have been employed to carefully watch the results. There are two common methods for measuring running water. The fundamental device is a flume or box placed in the ditch or canal, giving the water a rectangular cross section. The other method is by the use of weirs. In small canals and ditches, where the conditions permit, weirs have been installed. These weirs have their sides inclined from the vertical line at an angle whose tangent is one fourth. This modification of the rectangular weir approximately allows for end contraction, and the discharge formula of the rectangular weir

$$Q = 3.33(L - 0.2h)h^{\frac{3}{2}}$$

$$Q = 3.33\left(L - \frac{h}{5}\right)h^{\frac{3}{2}}$$

In many instances a weir cannot be employed. Where there is an excess of silt it has a tendency to raise the bed of the weir and destroy the relation between the depth of water flowing over the crest and the discharge. Where the bed of the stream is changing the weir is of little use. If the canal is very small the head of water cannot be spared and other methods must be used. Where weirs cannot be used the discharge is determined by making measurements of the velocity of the water and the area of the cross section. Where a flume is used the discharge is determined by making measurements of the velocity of the water and the area of the cross section. The velocity is determined by making as many measurements of the depth of the ditch as possible with different depths. In this way a series of coördinates are determined, one being the depths and the other

the corresponding discharges. With these observations an equation can be computed by means of the method of least squares, giving a special formula in each case. Where flumes are properly constructed and installed the curves are parabolic. No appreciable error would result if the general equation was assumed to be

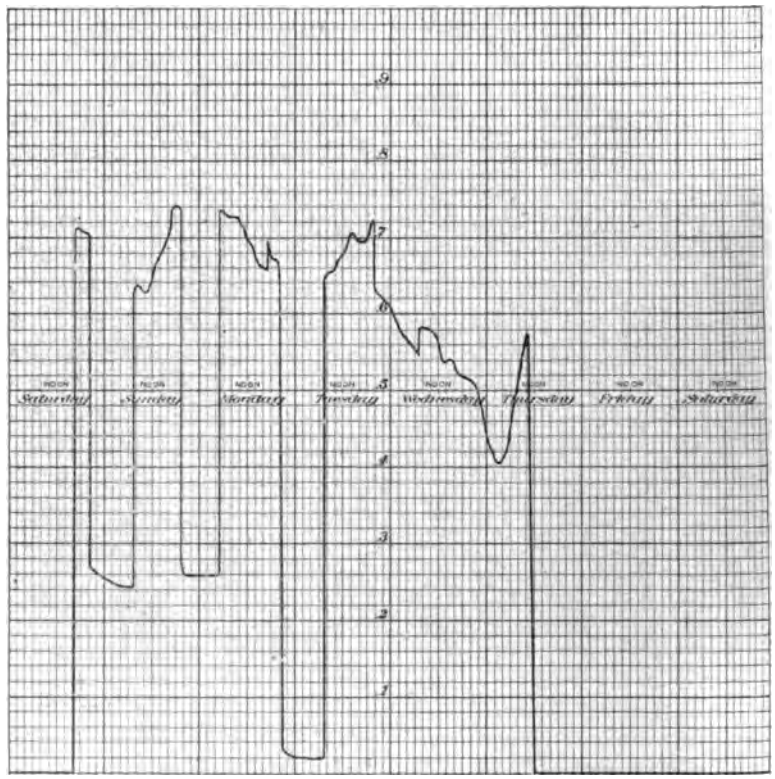



FIGURE 2.

$$Q = Ly^2 + my + n,$$

where Q is the discharge in cubic feet per second, y is the depth in feet, and L, m and n are constants which are determined in each case. It can be seen at once from this equation and the equation giving the discharge of the weir that the volume of water flowing in the channel depends on the depth.

erefore, a continuous record is kept of this factor, the results obtained converted into the total discharge for the period covered.

ome work has been done in this connection during the past fifteen years state engineers and experiment stations of the west. Several registers been designed for keeping a record of the depth, and they all do this or less imperfectly. I will not take space to describe these. Let it be ent to say that they all have their faults. The most serious is that of ing the record of depth. That is, if the water increased in depth one some of the registers indicate it by a rise of one-tenth of a foot; others eful weir or flume measurements, hence a new register had to be ed. This is shown in Fig. 1.

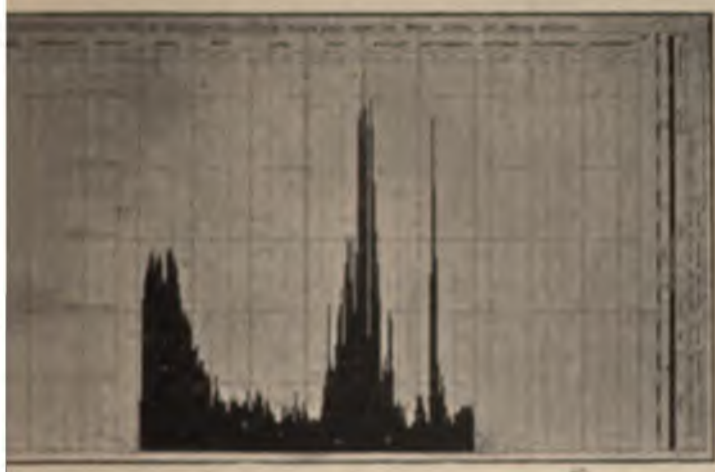


FIGURE 3.

consists of a horizontal cylinder which revolves with the rise and fall water. The mechanism for producing this motion is shown on the end of the cylinder. A clock running on guides parallel to the cylinder account of the time and travels seven spaces in a week. With this de- the exact fluctuations of depth are recorded at the time they occur. shows a sheet taken from the register.

glance the depth of water can be determined by any two-hour space. From the discharge equations, either for the weir or flume, tables have prepared giving the volume of water in cubic feet per second for vari-

ous depths. This table has been converted into a second one which gives the discharge for periods of two hours in acre-feet. The conversion is made by dividing the numbers in the first table by 6.05, that is, by 43560 ÷ 7200. The acre-foot is the most convenient unit for expressing large volumes of water, and is used almost exclusively in this office. With these tables and the register sheets which are sent in each week, the daily volume used in the irrigation of various crops is determined. Tables are made showing this volume in acre-feet, and from these tables diagrams are drawn showing the facts graphically. A diagram (Fig. 3), shown herewith, represents the amount of water used near Mesa, Arizona.

The column at the right shows the total depth to which the land is covered, including rainfall.

To make this work valuable, it must be continued for a number of years. As soon as the amount now used is determined, the station will be put under the charge of an experienced irrigator, and no water will be used except that which aids the growth of plant life. In this way the quantity of water needed will eventually be determined. When this has been done for localities of varying climatic conditions there will be a basis for a more equitable division of the water of our streams. At least one of the excuses now offered in defense of some of the ridiculous court decrees will vanish with the publication of the facts dealing with the duty of water. Those disposed to consider carefully the needs of irrigation law and its administration will, I believe, concur in the following statement:—

The work of finding the quantity of water requisite for the growth of crops, the measurement of streams affording the water supply, and the determination of the area of irrigated lands, must always be done by an engineer. After he has collected the facts and has become acquainted with the people and the local conditions as the field work will demand, he should be better qualified to fix the volume each man should receive than a judge having a lawyer's education and an inclination to follow precedents.

## HOUSE DRAINAGE.

A. B. RAYMOND, '91.

In considering the various causes affecting public health, house drainage cannot be omitted. To have a healthy community, we must have healthy homes for the people. One essential requirement for such homes

... fact supply of pure air within them To obtain this, poor ven ... the drawing and the fouling of the air by that from our drains ... to give our attention We know that those who live an out door ... are more ... than those who are confined indoors, also that as ... weather comes and our families are driven largely to indoor ... increases with little abatement until the warm ... again This indicates that the air we breathe, as well as ... and the water we drink has its part in causing poor health ... by air from our drains is very slight This ... fact that drainage work being mostly con ... of the conditions which actually exist

... from experience some of these sources and the ... into the house from them Ventilation to some ... buildings by the escape of the warm air within ... that air thus escaping must be replaced by a corre ... and it will always come in at the point ... Any openings upon the drainage lines within the building ... are involved The most common to be ...

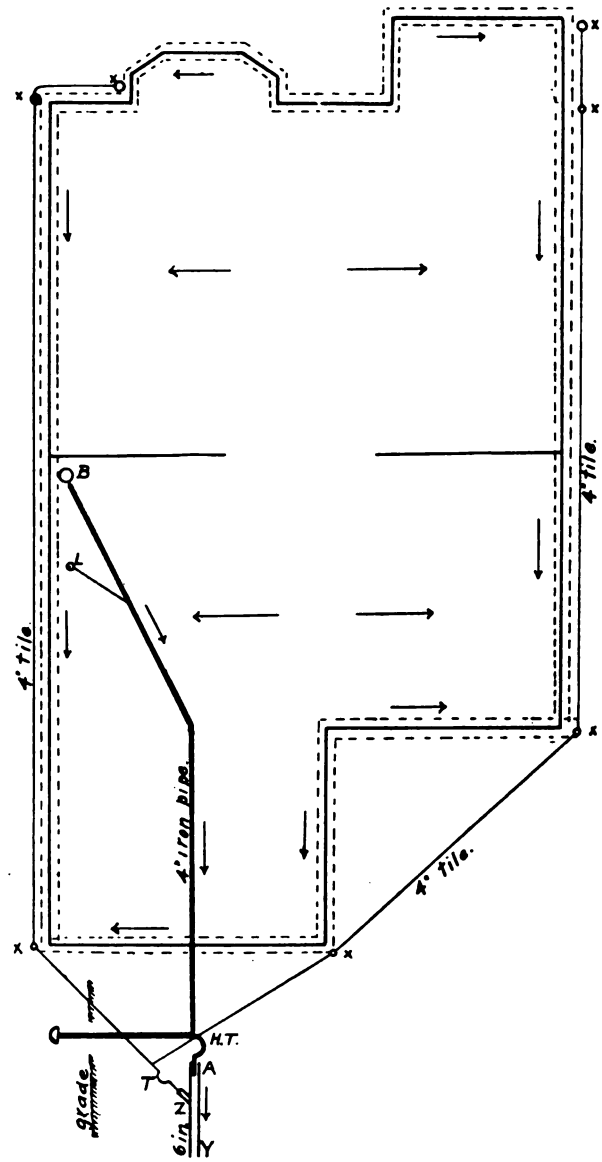
... to the house

... with the main sewer by untrapped ... the hopper closets

... account of using a sink for ... these receive the soil waste of the ... and another ... which such wastes the sewage finds outlet through the ... under the floor At the best a filthy spot in the earth that ... and the good air tainted

... We have found several very bad ... the part water building ... Barrel of Flour ...

... untrapped ... the main house drain ... from two ... and the water ... by the ... the current ... to make the drain ... extinguish the ... and ... a very common defect




GROUND PLAN Showing the soil and subsoil drains properly trapped and separate one from the other connecting into main drain to sewer at A and Z. A–Y Main house drain to sewer, 6 inch crock. A–B–I. Iron house drain, 4 inch receiving all soil waste. X–X–X–X–X Rainwater drains connecting into main drain at Z. H. T. House trap with fresh air inlet extending above grade. T. Rainwater trap for the entire subsoil system. Tile drains, crock, connecting into the rainwater B. Main vertical soil stack, 4 inch, extending through roof L. connection for laundry tubs.

[illegible] rage up in the soil system of the house. These are invariably [illegible]. The water seal is very slight and soon evaporated, as [illegible] used. This is a universal defect to be found upon all old [illegible]

[illegible] passage to the drains from loose joints where the iron and [illegible] are cemented into the cross drain under cellar bottom

[illegible] trapped sink and laundry wastes

[illegible] trapped, the seals are broken by siphonage from their own [illegible] or the discharge of other fixtures

[illegible] fixtures and unclean fixtures, especially water closets

[illegible] gases out of the plumbing pipes from poor workmanship [illegible] defective soil or toilet joints, coming into the living rooms

[illegible] passages left by careless workmen, such as changes in old [illegible] failure to close the waste when a fixture is removed

[illegible] most important and common defects from which certain [illegible]

[illegible] methods to close such places and one of the best [illegible] as it is they are the most readily brought to use [illegible] and which can be had anywhere, are manufactured for the purpose [illegible] passages, but can be used for stopping through them and [illegible] as the work can be started quicker in its course than [illegible]

[illegible] these and other evils which we find, steps are now being [illegible] "drainage and plumbing work" [illegible] Without taking time to go into details, I may [illegible] can point out the main requirements to be observed.

[illegible] should be [illegible] drainage work shall be done under the [illegible] and under the supervision of [illegible] plumbing work shall be executed [illegible] and accepted by the regular [illegible] Upon the proper [illegible] this work is done will depend [illegible] freedom from dampness. This part should have careful [illegible]

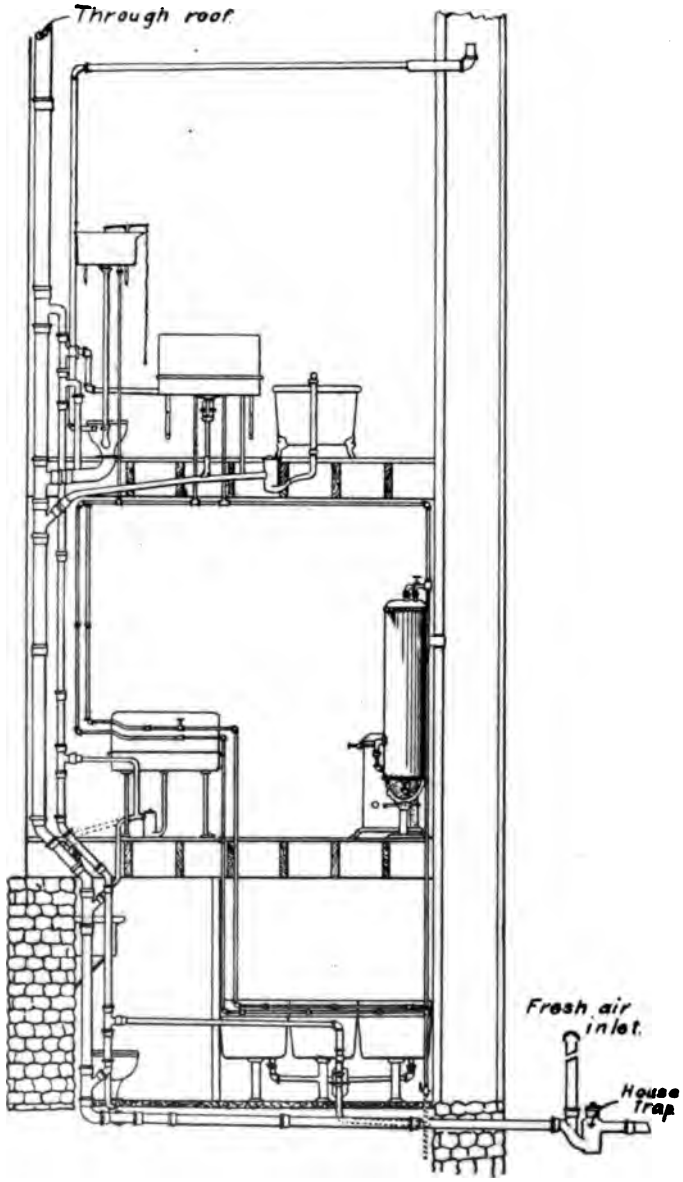



FIG. I.—A COMPLICATED SPECIMEN OF PLUMBING WORK.

[illegible] rely to the drain digger, and the last planned work [illegible] are [illegible] on his part. The requirement here is that they should be laid with a uniform fall to the outlet. The interior of the rain water [illegible] have a smooth surface and they shall be deep enough [illegible] and [illegible] drainage. These drains, which are called the [illegible] and rain water system, should not connect into the soil drain of the house, but should connect into the main house sewer outside of the house trap, being trapped just before entering [illegible] ground plan); thus they will be [illegible] from any air entering them from the main sewer and the rain water [illegible] by the rain water connections will keep the air within them cool and fresh.

The [illegible] and sink drains should connect into the rain water drains. The question may be asked, why not connect these lines directly into the [illegible] of the house? The reason is on account of the liability of a disengagement of the house trap, which would cause the house sewage to back into the house, [illegible] the entire system, and the formation of cesspools under the [illegible] as indicated on the defects to be found on old work.

In new work they are generally under the cellar bottom on account of the [illegible] covering the entire ground space, and also on account of saving [illegible] of digging. Whichever plan is adopted, the two systems should be kept separate as indicated, and for the reason given.

There should [illegible] trapping of the rainwater drains, as it is very rare [illegible] gases ever occurs on the main house drain outside of the house trap. They do occur, however, from faulty construction, careless workmanship, and where the lateral or main sewer is not sufficiently deep to carry off the drainage during a sudden storm without causing a backage from being restrained by the surface drainage.

Next comes the soil drain of the house. To protect the building against gas from the main or lateral sewer, just before or after it enters the house a trap is put upon it, and this is called the house trap. (See Figures 1 and 2.) This drain, commencing outside of the house, should be of iron, continued under cellar bottom and extended up through the building above the roof with open end. To this, just inside of the house trap, a connection with the outer air should be made for ventilation. This connection is called the fresh air inlet, or fresh vent. By this construction, a movement of the air is established through the soil system, keeping the air comparatively fresh within the lines.

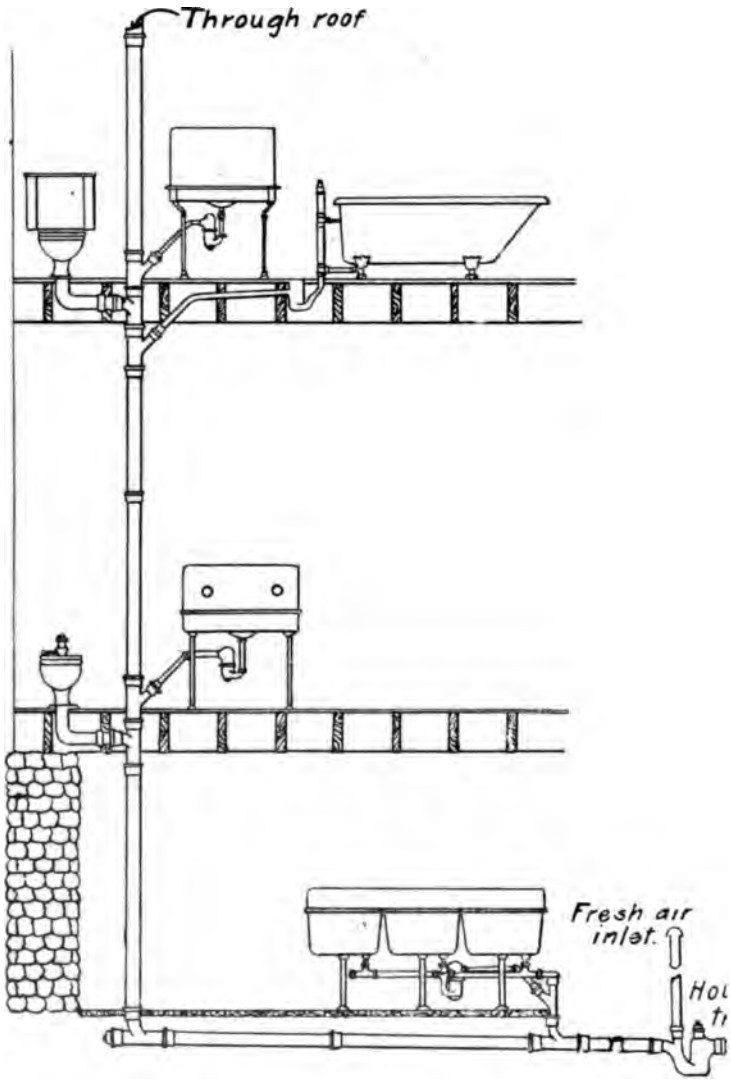



FIG. II.—THE MODERN STYLE OF PLUMBING.

Next the rooms of the building should be protected from the air from [illegible] frame themselves, for even with ventilation going on within [illegible] the air in them is more or less foul from the soil which collects upon [illegible] of the pipes. Therefore, all interior drainage pipes should be of [illegible] cast or wrought iron. When the pipes are in place ready for the [illegible] and before being covered, they should be required to stand the water test. After the fixtures are placed ready for use, the work should [illegible] to stand the smoke test. The manner of making the latter has already been indicated. The water test is made as follows:—

When the rough work is all in ready for the fixtures, the various openings are securely closed and the pipes filled with water to the top of the [illegible] which extending through the roof. The water is then allowed to [illegible] for an hour or so to see if the level is maintained. If not, there is [illegible] and it must be found by search and remedied before the work is [illegible]. This can be easily done before the work is covered. There are many [illegible] to deceive the inspector in making these tests, and he should be one [illegible] to the tricks of the trade. A good inspector is seldom caught, [illegible] means to detect fraud, and he should always be on the lookout [illegible].

Next comes the protection of the fixtures from air passing through [illegible] in the drain when they are discharged. Each fixture must be separately trapped and every trap protected from syphonage caused by its own discharge or by the rush of the discharge of any other fixture. This is generally done by what is called a system of venting to afford relief from any possible [illegible] suction. An independent pipe, the same diameter as the main [illegible] is run parallel to it, either extended through the roof or connected [illegible] the wall above the highest fixture, and into this connections are made [illegible] crown of each trap. Experience has shown that this system is not always safe on account of these vents becoming stopped from various causes. They are then a source of danger on account of fancied security [illegible] which does not exist. Much of the venting is now discontinued and reserved [illegible] anti-syphon traps. In work properly designed syphonage may be largely avoided. The danger points are where the [illegible] are made into the side of the horizontal [illegible] or else into the [illegible] level. Connections taken off the [illegible] safe against syphonage [illegible] of [illegible] work.

For an illustration of the [illegible] of this subject [illegible]

compare that in Figure 1 with that in Figure 2. These plates were taken from the Christmas issue of the Plumbers' Trade Journal of New York, 1899-1900.

In conclusion, anyone who is about to build should consult with those who are in charge of the plumbing and drainage work. Their advice will often save useless expense and protect you from unsanitary construction. In any case, you have nothing to lose but everything to gain by so doing.

## SINKING A PNEUMATIC CAISSON AROUND A BRIDGE PIER

EDWARD M. ST. JOHN, '95.

Of all the methods in use to get a good foundation for heavy structures, the pneumatic caisson method always seems the most interesting, the most wonderful. The idea of working one's way through water, mud, sand, rock, etc., to a depth of over one hundred feet below the surface of the water, and of keeping the water out of the way by means of compressed air, is one of the triumphs of modern science.

When, therefore, a chance was given the writer to assist in sinking a caisson, he was very glad to go, even though the country thereabouts had a reputation of making all new comers sick with chills, fevers, etc. It was about the middle of November, 1898, that the trip was made to Little Rock, Ark. It was a night ride, and daylight came when we were about one hundred miles northeast of our destination. The view was dreary, indeed. At least one-half the country that we passed through was flooded with water. Now and then we passed a shanty or cotton field, with some natives standing around waiting for the waters to dry up. We were told that the country was not flooded like this all the time. Finally Little Rock, the "Rose City" as it is called, came in sight. The presence of some huge rocks on the banks of the Arkansas River suggested the name "Little Rock" to the founders. A much larger rock two or three miles up the river is called Big Rock. Two of the bridges across the river at this place are owned by the St. Louis, Iron Mountain & Southern Railway Co. One of these consists of four fixed spans, through Pratt trusses, and one swing span, making altogether about twelve hundred feet of bridge. The piers are of stone masonry resting on timber caissons sunk to the rock about forty-five feet below low water line. These piers and bridges were built in about the year

[illegible] Sheet's after being built, the pivot pier, holding up the swing span, and one other pier began to lean up stream. This threw the bridge out of line and it had to be moved back and wedges put under to level it up in order to operate the swing span readily. The leaning continued, however, and in the summer of 1888 the top of the masonry overhung the bottom by over a foot and the turn table drums had been moved over as near one edge of the pivot pier as was safe to put it.

It was then decided to stop the leaning if possible, and the contract was let to the Missouri Valley Bridge and Iron Works, of Leavenworth, Kas. Mr. A. J. Tullock, chief engineer, and Mr. L. S. Stewart, superintendent of the work. Work was commenced in September, 1888. A pneumatic timber caisson was to be sunk surrounding the pier. This part was of itself a very difficult task, owing to the large size of the caisson, the swift current and rapid shoaling of the water in the river, and to the materials encountered on the bottom of the river.

As the caisson was to be sunk around a pier already built, it could not be put together on shore and floated into position, but had to be built above water at once and the pier on a pile support and then lowered into the water. As there were not more than five or six feet of sand overlying the rock beneath the river bottom the piles had to have an extra amount of bracing to keep them upright. The load was to be quite considerable and at a height of about four feet above low water mark, making about forty five feet that the piles extended above the yielding sand in the river bottom. This bracing was accomplished by making a loop of chain about eighteen inches in diameter, spiking it to the end of a 6"x12"x18' plank, then setting the loop down around one of the piles with the plank held nearly vertical till it was about fifteen feet below the water surface, and the loop being then around the pile and plank, the top of the plank was to be eight feet, tightening the chain as it came till the end [illegible] could be brought to another pile where it was securely spiked.

The masonry pier [illegible] feet [illegible] square timber cribwork two feet on a side. The [illegible] underneath reaches up to [illegible] water mark. The new caisson to be sunk around this was [illegible] pier being forty six feet [illegible] rapidly forward the [illegible] top till finally the [illegible]

side, leaving seven feet between the old caisson and the new, and twelve feet between the outer and inner walls of the new caisson. Six feet above the bottom or cutting edge of the new caisson was a roof built in from wall to wall, the space underneath being the air or working chamber, and the space above for sand filling to give the weight necessary for sinking. Southern pine sticks 12"x12", dressed on four sides, were used in building. The pine was from the Arkansas forests and was a fine lot of timber. Whole carloads would be unloaded of pieces twenty and twenty-six feet long with hardly a knot in them. As no objection was made to sap, there was some sap in the pieces used. The timbers in each course were dapped together, and the the courses were drift bolted together. Drift bolts were seven-eights ins. in diameter by two feet ten inches long, and were driven into holes bored one-sixteenth of an inch less than their own diameter. In this way each course was securely fastened to two courses below. Drifts were spaced about three feet apart. Seven courses of the caisson were put together on the pile support before it was lowered into the water. This included the cutting edge and the sides and roof of the working chamber. The sides of the chamber were three and one-half feet thick, and the roof two and one-half feet thick. All spaces between timbers in the chamber and on the outside of the walls were carefully calked with oakum.

The lowering of the caisson into water was accomplished as follows: Imagine the caisson resting on the floor beams of a bridge and instead of the usual hangers at the ends, screws three inches in diameter are used. These screws run up through a 12"x12" cap on the piles, and nuts are screwed on from the upper end down against this cap, or rather against a washer on the cap. By turning these nuts the floor beams could be raised or lowered, and with it the caisson. Wrenches with handles five feet long were used to turn these nuts, and three men operated each wrench. Twenty-four of these lowering screws three inches in diameter by twenty-two and one-half feet long were used, and about eighty men were needed to operate them. All the nuts were moved simultaneously, the "course around" shouted by the foreman being the signal for every man to move his wrench a quarter turn. The lowering was done at the rate of about one foot per hour.

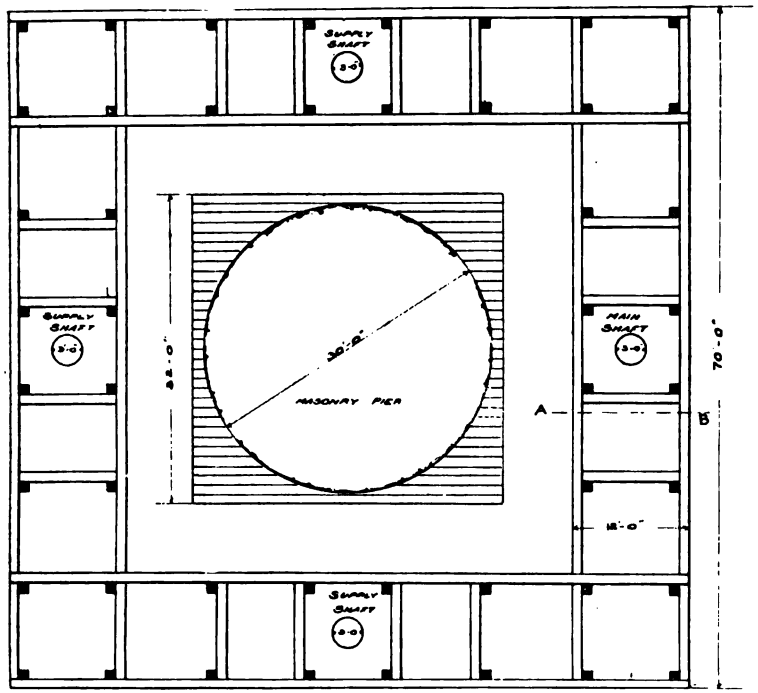
A calculation of the weight of a cubic foot of timber was made from the displacement in the water. It was forty-five pounds. This was for unseasoned pine cut about one month.

It was a great relief to get the caisson floated. The building now went

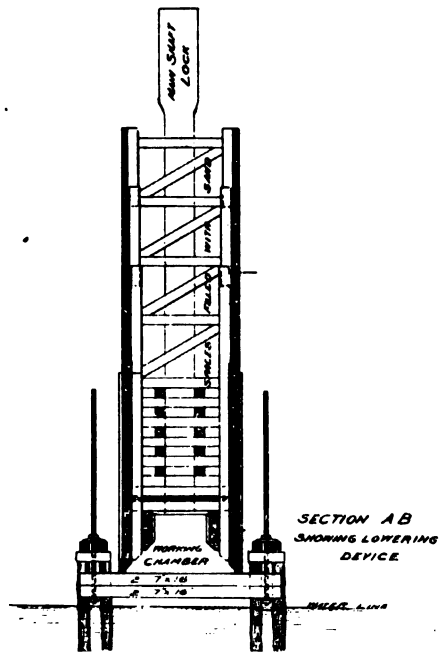
[illegible]

[illegible]

[illegible]




PNEUMATIC CAISSON USED AT
LITTLE ROCK JUNCTION BRIDGE
LITTLE ROCK, ARK.




SECTION AB
SHOWING LOWERING DEVICE

... to start the excavation. Although the cutting edge ... was around, the space between in the chamber ... and while in some places the bottom of the river ... others the water was several feet deep. Only ... chamber at first. The number was increased ... made for more till the number reached eighteen or ...

... to be gotten out were sand, consid- ... before mentioned, and some old piles that ... bottom of the river. These old piles were ... rapid sinking an impossibility, as they had to be ... a foot or two at a time. When it was possible, a hole ... a piece of dynamite was put in and exploded ... the pile off even with the hole.

... getting the sand out, the methods being ... This was the "wet blow out," and the other the ... through the roof of the chamber protruded the 4 in ... placed along at convenient intervals. These ... ends that were in the chamber. The other ends ... of the river. To the end in the chamber, a rub ... diameter and 15 feet long was attached. On ... was a nozzle with a three inch opening. This ... the water and into the sand and the valve opened ... sand and water up at great speed. When material ... and not too coarse this method works very well.

... method was used when the materials, though not ... with, would be too large being blown out. The mate ... the nozzle was brought near and the valve ... and forced up and out. Stones two or three ... were sent out in this way and buried three or four hun ... along the upper end of the discharge pipe.

... was a 4" × 8" oak strip securely ... 8" oak formed the edge. Excavation ... under a part of it in order to ... was reached the descent was of course ... and as hard as ... Its surface was very uneven. When it was first reached

there were other parts of the cutting edge that had nearly five feet to go before reaching it.

At this point let us take a trip into the caisson. It is now down in the rock part of the way around. We first prepare for the trip by putting on some old clothes, as the mud is over everything down in the "hole." Also some high-topped rubber boots. We also leave our watches behind as the compressed air usually does some mischief by making them run faster or slower, or stopping them entirely. Tied to the part of the caisson that is above water is a house boat called the "Sand Hog" boat after the Sand Hogs, who are the men who work at excavating under compressed air. This house has two compartments, one for the white men and one for the black. There is a stove in each kept red hot most of the time to dry the clothes of the men who are off duty.

After inspecting these quarters, which are kept as clean as one man can keep them, we go out and onto the caisson. A large round cylinder is in front of us, rising up through the sand filling. It is about four feet in diameter and reaches fourteen feet above water. This is the lock. About ten feet down from the top it reduces in size to fit the 3-foot shaft that reaches to the chamber below. If any one has a cold or his heart is weak he had better not go down. The outside lock tender gives five raps on the lock. It is answered by five raps from the inside lock-tender, who proceeds to let the air out of the lock before the door can be opened by which we go in. This door is in the top of the lock four or five feet above our heads. As it opens a dense white fog comes out, and then up through the fog comes the head of the man inside. We climb up a ladder and down through a small door two feet in diameter and are inside the lock. An incandescent electric lamp lights the place. There is a peculiar odor, rather disagreeable, that comes up from the region beneath. It is a small place. Standing on one side you can stretch out your hand and touch each person in there.

The outside lock tender now pulls the door up with a block and tackle. Air is now let in from the shaft beneath. It has the sound of escaping steam. Almost immediately some one cries out. The air valve is quickly closed. The pressure of the air on the drums of his ear caused a sharp pain. He is told to work his jaws up and down or to hold his nose, close his mouth and force the air from his lungs into his mouth, or to do the act of swallowing. This is to open the passage from the mouth to the ear so

Sixty feet from the first turn is another turn at right angles. We have to go through some bulkheads to get by the corner. These bulkheads are to give strength and stiffness to the caisson, the corners being points hardest to make strong. Just after turning the corner out of sight of the workmen a dull thud is heard. It is the explosion of about a pound of dynamite within fifty feet of us. The noise is very much deadened.

A little farther on we come to some men drilling holes into a large "nigger-head" stone of about one cubic yard volume. It is a loose stone, very hard, and will have to be blasted into small fragments before it can be gotten out. The drills used are ordinary chisel drills held by one man who gives it a slight turn after each blow given by another man.

We go on around till we come to the shaft through which we came down. We have made the circuit around the pier a distance of 250 feet. The climb up the ladder is more difficult than the climb down, and if one is not very strong one is likely to have a feeling of exhaustion at this time which would not be produced in open air with twice the amount of exertion. One lives faster, the heart beats are increased, and a very noticeable amount of exhilaration is felt.

We go up the ladder and into the lock, the door beneath is pulled up, the outside lock tender is warned that someone is coming out, giving five raps for an answer. The air is equalized in the lock faster than it was when we came in. We feel the air coming out of our inner ears, and at the same time the temperature in the lock goes down rapidly. A dense fog is formed. As soon as the air pressure is the same as that outside the door in the top is let down by the man outside and we climb out. The trip has certainly been worth the trouble. Although the pressure is not half what is sometimes used, it is enough for the first time.

The work of excavation in the chamber was carried on night and day, the men working in three shifts of eight hours each. One of the shifts was composed entirely of negroes. Their work in this line was very nearly as good as that of the white men. They could not be depended on in an emergency, however. They lacked nerve.

The pressure was not great enough to cause much of caisson disease or "bends." There were only two or three cases, and they were not serious. One negro who was getting over an attack, when asked if it hurt more than rheumatism, said: "Oh yes! Wusser, much wusser."

The rock and coarse materials in the chamber were hoisted out in buckets through supply shafts. These shafts were three in number, placed on

## THE DRAFTING ROOM OF A BRIDGE OFFICE.

R. G. MANNING, '90.

After completing the course of studies in engineering, there is really only one thing lacking to start the young engineer toward success. That one thing is opportunity. Many a successful engineer can trace his success to the right opening that gave him a chance to start. The young engineer is being sought after more each year, and the opportunities to get started are on the increase.

A large number of these opportunities present themselves each year in the drafting rooms of bridge and structural steel works. When a young engineer secures one of these positions, he must show a disposition to learn, work hard, and be willing to do anything. Willingness to take hold of anything will be a large factor to rapid advancement. Too much stress cannot be laid upon the theoretical side of the engineering course. Well grounded theory is the foundation to practical success.

The design and building of a steel structure may be compared to that of a frame building in which all the nails would be located and holes made for them before putting the boards together, all the pieces of lumber would be laid out and sawed to fit before being put in place, the difference being that if the parts of the steel work do not fit when put together, it is not as easy to recut and shape them as it is with the lumber. If the pieces of steel do not fit when put together, they are often spoiled and must be thrown away. It is often difficult to get the pieces of material to replace the rejected parts. The material for a bridge is ordered from the rolling mills to shape, size and length required, assuming that nothing will be spoiled, just the same as lumber for a house is ordered from the lumber yards. The rolling mills are often hundreds of miles from the bridge shops, while lumber yards are usually in the community in which the house is being built.

The comparison above will serve to illustrate the truth that one of the most important requirements of the drafting room is accuracy. The most careful and painstaking man will make mistakes, but the more nearly a person's work is free from mistakes, the more it will be appreciated. Accuracy should always have the preference over rapidity. Rapidity, or hurried work, is almost always accompanied by a larger number of mistakes, or a slackness of the work in one place or another. Work rushed through an

[illegible] care and attention is almost always accompanied by a [illegible] in correcting mistakes in drawings while passing [illegible] saved in the first place, besides the expense of [illegible] that may not be found till the work is erected. The draw[illegible] of this kind are unsatisfactory and should be avoided as far [illegible]

[illegible] force of a bridge company is usually divided into two [illegible] the estimating and the detailing.

[illegible] the estimating department is to prepare the estimates of [illegible] all work that the company bids upon, prepare all stress [illegible] preliminary plans when required, and they must secure all data [illegible] necessary in preparing the detail plans. Sometimes the [illegible] estimates are furnished by the parties wanting the work [illegible] figure the weight and estimate the cost. It [illegible] the stress sheets and preliminary plans must be worked [illegible] data furnished. When plans are furnished they are usually [illegible] engineer in the employ of the party wanting the work or [illegible] engineer who has charge of the work. The work [illegible] one of two ways, so much per pound of shipping weight [illegible] the work complete. The one is called a pound price and the [illegible] sometimes erected complete ready for traffic and some[illegible] other ways. In a contract plan the party having the [illegible] has most of the

[illegible] drafting department [illegible] the detailing of partners [illegible] the [illegible] department and make [illegible] plans. [illegible] that a set of drawings [illegible] shop with the [illegible] [illegible] [illegible]

A shop that turns out 6,000 to 8,000 tons of work per year requires a drafting force of about eight, distributed about as follows: the chief draftsman; two men of experience who can handle any kind of work, one or both being classed as checkers; three man to detail the bulk of the work and sometimes doing their own tracing; two men to do tracing and who will work into detailing. This makes a drafting force of eight, scaling up in experience. Three years' experience in the drafting room should make an engineer familiar with the ordinary work that comes up.

We will now take a bridge from the beginning and trace it through the different steps until it is finished and turned over as completed to the parties buying it. We will assume that a railroad company desires to contract for a bridge. The chief engineer will write to the several bridge companies from which he desires to receive bids, giving the length of span, location, specifications for loading and material, and any other conditions that may govern this particular bridge, and the date of receiving bids. The estimating department takes the data given, prepares the stress sheet, figures the weight of the bridge, and makes an estimate of cost. The bids are received by the railroad company, and we will suppose that the bridge company we are considering receives the award of the contract. It is usually presumed that the lowest bidder gets the contract, although the time of delivery and other conditions may alter this. In the letting of public work where the plans and specifications are definite, the lowest responsible bidder gets the contract.

After the contract is secured, all the data required to get out the details of the work are turned over to the chief of the drafting room. This data will include the stress sheet, specifications, and a data sheet, properly filled out, containing a list of items that usually come up in working out the details. An order for material must first be made, and this may require sketches of such details as are not determined by the data furnished, as every piece of material ordered must have a place in the bridge and every piece required must be ordered.

This material is usually inspected at the rolling mills by someone employed by the railroad company, and must meet the requirements of the specifications. This order for material is turned over to the person whose business it is to place the orders with the rolling mills and furnish the inspector with a copy of the same. It is a good plan to check the weight of the material ordered with the estimated weight of the bridge.

ordered the work may be laid aside until a com
work up the details, unless the necessities of the case
The data is then all turned over to one or
may require, to make the detail drawings. The chief
the data with the draftsmen, making such explana
and out the manner in which the drawings are to
planning each set of drawings
The drawings are then completed and traced
drawing then to pencil. If drawings
they are usually sent
as the tracings
checking in order to save time
general dimensions and diameters are correct,
the
the parts
checking
information given on the drawing and that
figure
drawing
figure
drawing
be made
The
the
the
the

The first work in the shop is to make the templates. Almost every different piece of material is first laid out on boards, the holes bored in their proper places, each piece marked, giving the number required, and any other necessary information. These pieces of boards are called templates, and are used for laying out the work on the pieces of steel by clamping or holding the templates on the pieces of steel. There are from one to eight pieces of each kind for one span of a bridge and the templates are used on each piece, making one template serve to lay out as many pieces as there are of that kind. One template often serves for more than one kind, where they differ only slightly, by properly marking the templates. Where rivet spacing is symmetrical about a center line, only one half of the length of the piece need be laid out on the template. Some of the large plates are often laid out on one of the plates itself, punched and then used as a template, as it would be too expensive to provide the lumber on which to lay it out.

The work then goes through the process of shearing, punching or drilling, assembling, reaming if required, riveting, milling, boring, inspection, painting shipping, and erection. A draftsman should visit the shop frequently to see how the work is done and acquaint himself as much as possible with the practical side of the work.

All the work of the drafting room should be checked by some one other than the person who made the original. This cannot always be done but should be carried out as far as possible. The work of this department is final and is so important that every precaution possible should be taken to eliminate the errors. It usually results in a saving of time to have the work thoroughly checked as all mistakes will be discovered before the work has passed through the shop and is erected, and it takes a great deal more time to look up mistakes and correct them after the work is laid aside than it does to do it in the regular way while the work is fresh in the mind. When it is remembered that there are hundreds of figures and relations of parts on every drawing, and that they pass through the steps of preliminary computations, transferring to the pencil drawing, and tracing, with so many chances of misconception, it is very important to have the final work thoroughly checked.

The tools necessary for a draftsman in a bridge office to have are two 45° triangles, 4-in. and 10-in.; two 30° and 60° triangles, 5-in. and 13-in.; two good right line pens; one good 42-in. T square, one that is stiff and

complete one bow pen, one bow pencil, one
pencil and ink erasers, scratcher, and
a place in the tracing cloth that has been
surface and prevent the ink from running. Trans-
with celluloid tapes are best.
wrinkles of the drafting room will be found in

marks removed from the tracing with
and copy to the tracing. Lay the tracing
paper that is not wanted before applying the
and with spool pencil. Erasing
about the drafting room by wash-

prints is obtained by developing
can be obtained at dealers in
will run and blot the lines of the

pencil the work on the tracing cloth
pen, using clean paper and tracing. The

the border line. If a stamp is used for all of the title except that which describes the work on the sheet, the titles will be more uniform and will add considerable to the appearance of the drawings. The title should be made plain and prominent for ready reference in the files. It should contain the contract number, sheet number, general title of the work, the special work on that sheet, scale, date, name of detailer, tracer and checker, and name of bridge company. In the lower right hand corner a circle three-quarters of an inch in diameter with a horizontal line through the center, having the number of the sheet above the line and the total number of sheets in the set below the line, makes a convenient means of reference. This sample of title will serve to illustrate.

The writer prefers to file the tracing flat in a drawer, one drawer containing as many tracings as is convenient.

The best way to stretch tracing cloth on a drawing board is by means of small one-half ounce tacks. The tacks are driven into and removed from the board by means of a special hammer made of ½-inch round steel and tempered. One end is turned over at right angles to the length so that the end is ¾ of an inch from the inner face, and the other end is straight and sharpened like a chisel. One end is used for driving and the other for removing the tacks. The whole is about 6½ inches long. This hammer is

## EDITORIALS.

We wish to impress upon the graduate members of the Society the great convenience they may confer by advising *The Technic* of any change of address. It is almost impossible to keep the mailing list correct from year to year. *The Technic* is mailed to all to whom they are due, but of course are not received if the member has changed his address. We are often in receipt of letters asking why *The Technic* has not been received, although through no fault of ours. If any one who has changed his address will notify the managing editor of the Technic Board, it will not only be a great aid to the board, but will insure the prompt receipt of the *Technic*.

It is gratifying to know that the Mechanical Laboratory is to be considerably enlarged the coming summer, and among the apparatus which is to be placed in it is a compound marine engine, now being designed by some of the students, to be used in some of the courses in the recently established department of marine engineering. The offer to become junior professor of naval architecture has been accepted by Mr. H. C. Sadler, of Glasgow, Scotland.

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# TENTH ANNUAL BANQUET

OF THE

## Engineering Society

OF THE

## University of Michigan

* * * * *

*aturday Evening*
*lay 12, 1900* · · Hangsterfer's Hall

* * * * *

## *Committee*

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*P. A. DRATZ, 1900*
*E. W. KIEFER, 1901*

***Welcome by the President*** . **GEORGE D. WUERFEL**

"As to the inner man the food is,
So is the feast of reason to the mind."

# *Toasts*

***TOASTMASTER--J. WALTER WOOD.***

"By my troth, we that have good wits
have much to answer for."

***1903,*** . . . . . **J. E. McAFEE**

"A little child shall lead them."

***1902,*** . . . . . **F. C. CUMMER**

"On thy chin the springing beard began
to spread a doubtful down and promise man."

***1901,*** . . . . **GEORGE HUDNUTT**

"Bid me discourse, I will enchant thine ear."

***1900,*** . . . . . **FRED LOUD**

"From the beach we view the ocean."

***The Technic,*** . . . . **ALFRED LINDAU**

Books are needed, but not many books,
A few, well read.

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A light to guide, a rod to check the erring and reprove.

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**PROF. ZIWET**

"That boy with the grave and mathematical look."

**PROF. DENISON**

"He is the very pink of politeness."

**PROF. ALLEN**

"Ah me! What perils do environ
That man who meddles with iron."

**CARROL D. JONES**

"This is a goodly sort of fellow."

**PROF. M. E. COOLEY**

"He's keen but never cuts."

# *Third Annual Banquet...*

OF THE

# Chicago Engineering Alumni

of the

## University of Michigan

SATURDAY EVENING, APRIL 21, 1900 AT
CHICAGO ATHLETIC ASSOCIATION

* * *

*Committees:*

ARRANGEMENTS--
L. K. Comstock, '88
A. K. Adler, '94
G. A. Damon, '95

PROGRAM.-
E. H. Cheney, '92
G. M. Wisner, '92
F. S. Richmond, '91
C. G. Atkins, '93

INVITATION--
C. W. Whitney, '99
R. M. Shankland, '88
W. L. Stebbings, '83
A. M. Haubrich, '95

MUSIC--
W. J. Cahill, '96
J. D. Hibbard, '87

# The Banquet

Held at the club rooms of the Chicago Atheletic Association, again proved to be a thoroughly enjoyable event to the Chicago Alumni of the Engineering Department. There were about sixty in attendance from Chicago and vicinity. There were also present Professors Charles E. Greene, J. B. Davis and C. S. Denison, of the University, besides several from Ann Arbor and other cities. Before the banquet an informal reception was held. No regular program of toasts had been arranged. Mr. R. P. Lamont, president of the Alumni Association, acted as toastmaster and called upon various ones for informal remarks, which were interspersed with songs and college yells. Those who responded were:

| | |
|---|---|
| PROFESSOR GREENE | PRFFESSOR DAVIS |
| PROFESSOR DENISON | ALFRED NOBLE, '70 |
| WILLIAM A. OTIS, '78 | O. C. SIMONDS, '78 |
| THOMAS O. PERRY, '72 | JOHN D. HIBBARD, '87 |
| GEORGE B. SPRINGER, '90 | RALPH M. SHANKLAND, '88 |

HORACE C. ALEXANDER, '82

During the banquet a ballot was taken and Mr. Alfred Noble, '76, was elected president for the ensuing year. The president appoints the secretary, and this has not yet been done. Mr. C. W. Whitney was secretary during the past year.

Some Publications of

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**A Text Book of Elementary Mechanical Drawing for Use in Office or School.** By Clarence [illegible] and Herbert J. Golding, B. S., M. E., *Instructors in* [illegible], *and Draughtsmen at the University of Michigan.* Quarto, 100 [illegible]

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**The Theory of Substitutions and Its Application to Algebra.** By Dr. Eugene Netto, [illegible] in the University of Giessen. Revised by the author [illegible] by his permission, by F. N. Cole, Ph. D., formerly Assistant [illegible] University of Michigan, *Professor of Mathematics in* [illegible] 160 pages. Cloth $1.00

**Mathematical Theories of Planetary Motions.** By Dr. Otto Pulisch, *Privat-Docent at the* [illegible] *Translated by Mark W.* [illegible] *formerly Chief of the United States Weather Bureau and Professor* [illegible] *and Director of the Observatory at the University of Michigan,* [illegible] *of the University of Washington, and Wm. J. Hussey, Assistant P.* [illegible] *in the Leland Stanford, Junior, University.* 8vo. 291 pages [illegible]

**Algebra.** By D. Mac A. Lyman, A. B., Assistant in Hall H. S., and Edwin C. Goddard [illegible] *Instructor in Mathematics, University of Michigan.* Octavo, 75 pages [illegible]

**Laboratory Manual and Elementary Chemistry.** By James Montgomery, Ph. D. [illegible] *Ann Arbor High School* and Roy H. Smith, B. [illegible] *Ann Arbor High School.* 12mo. 140 pages [illegible]

**Brown's [illegible] Plane Surveying.** By William P. Brown, [illegible] Training, Michigan State Normal College. With 11 [illegible] 12mo. [illegible]

**Lloyd's [illegible] Law of Wind.** [illegible] By Nathaniel H. Lloyd, [illegible] University of Michigan. [illegible] Octavo, [illegible] Mathematical and Physical Division. Paper, 10 [illegible]

[illegible] Correspondence invited.

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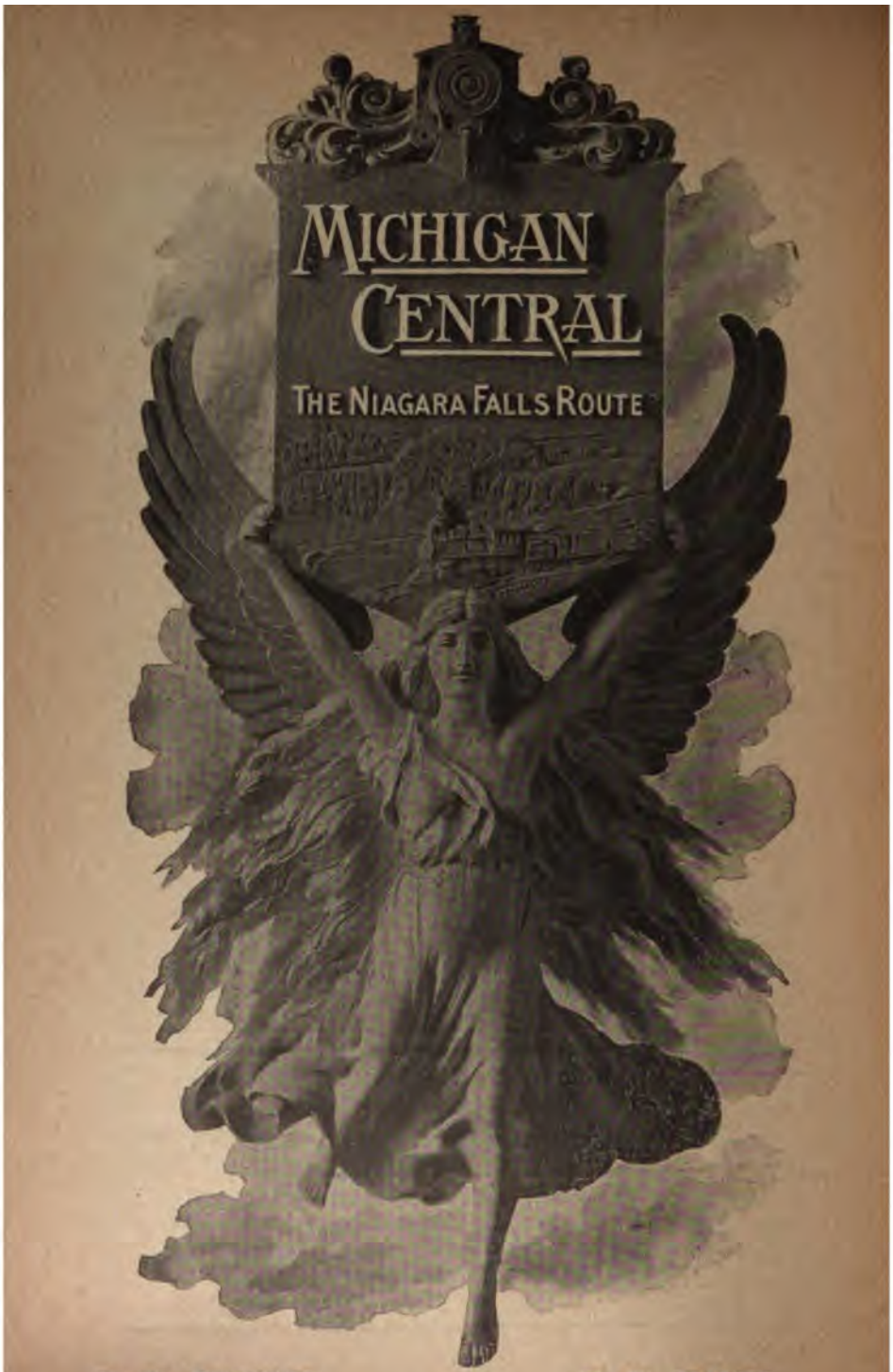


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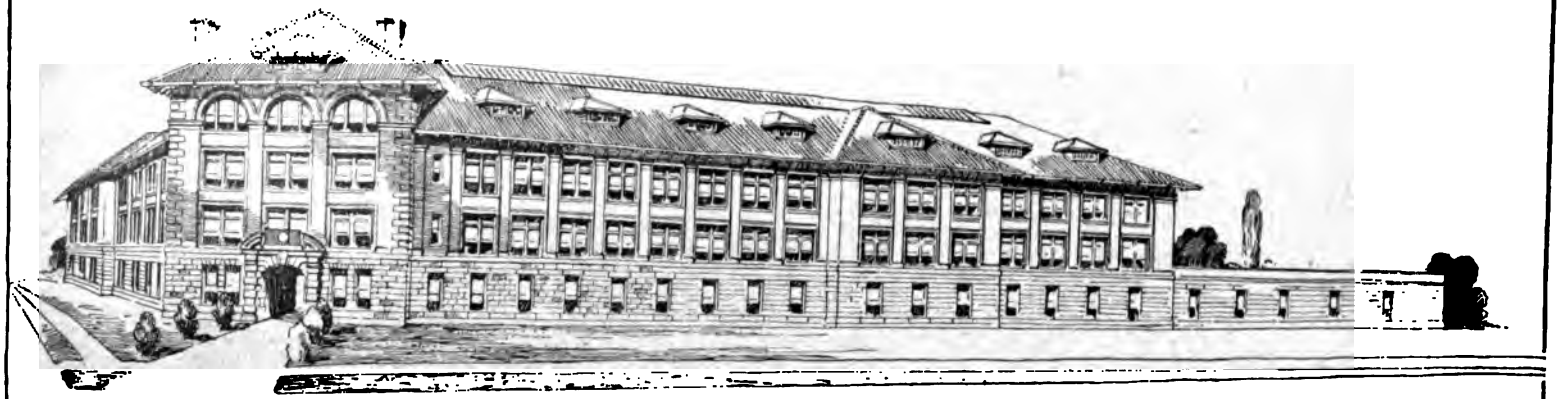

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BY

in the physical constructive realm of the world's work, together with the honorable rewards incident to successful achievement, have largely enhanced the newer conception of the engineer's position.

One of the notable results of this increasing public esteem for the profession is a more than willingness on the part of governments and of private wealth to provide liberally for the suitable and dignified housing and equipment of engineering schools, where able and earnest young men may be thoroughly trained to become, literally, the constructors of the future.

Doubtless it is in this spirit of an enlightened comprehension of new conditions, as well as a conviction of the imperative, immediate wants of the engineering department, if it is in any adequate way to fulfill its function to the state, that the Board of Regents of the University have unanimously entered upon a liberal policy toward the Department. At the last meeting of the board plans by Mason & Kahn, of Detroit, were adopted and the erection of a new engineering building determined upon, which, when completed, will not only relieve the present encumbered and congested condition, but will form a fitting establishment and home for the Department, affording adequate accommodations for both the faculty and students, as well as a safe and commodious shelter for the constantly augmenting collections of models, apparatus, instruments and equipment. Beyond question this new plant, with its convenient arrangements and thoroughly up-to-date fittings will by the saving of time and energy alone enormously increase the efficiency even of the present teaching force, and in numberless ways add to the facilities for the acquisition of knowledge, to say nothing of the actual working convenience and comfort of the student body.

To the "old graduate" and those of the faculty who recall conditions existing say twenty-five years ago, the new installation will present some striking and most encouraging contrasts.

For many years the engineering classes occupied three or four rooms only in the old South Wing of University Hall, rooms formerly used for student dormitories in the early days. They were heated by wood stoves stoked by the professor or an obliging student from immense wood-boxes, daily filled by "Jimmie" Ottley,—the same "Jimmie" long since promoted to an easy berth in the cloak-room of the Library. The water needed for the drawing room was supplied from a battered zinc pail, refilled from time to time as use demanded. It was a restricted environment.

"With creaking stair and wind-swept hall"

and old pine drawing desks "scarred by many a truant knife," but a great deal of excellent work was done there, although under very disadvantageous conditions and heavily discounted by the lack of accommodations.

at the right and left of the arcade and one in the west central part of the East Wing. On all floors will be located toilet-rooms for students and faculty and an abundant water supply. Lockers and closets, vaults and filing-rooms for the proper and safe storage of papers, drawings, and accumulating data.

The entire building will be warmed by direct radiation and ventilated by fans or blowers delivering 2,000 cubic feet per occupant per hour. The steam will be distributed overhead in passages or ducts near the outside walls of the building. The returns will be carried in a special duct under the floor of the basement corridor.

The South, the East, and the North Wings will have separate fans. Those for the South and East Wings will have a 7 foot running wheel and for the North Wing a 5 foot running wheel. These fans will be driven by direct connected electric motors.

The fresh air duct is formed by a false ceiling three feet down from the main ceiling of the basement corridors, giving a flue of thirty-three square feet area. From this main flue vertical flues rise in the corridor walls throughout the entire length of the building.

The air for ventilation will be warmed to only 75 or 84 degrees and will not be depended upon for heating the building, except in mild weather. At the close of work in the building the ventilation may be entirely shut off and the warmth of the building maintained by direct radiation. This system affords the maximum economy possible with adequate ventilation when the building is occupied.

The vent flues discharge into a large duct over the corridor, on the fourth floor, this main duct leading to the towers of the central wing. Separate ventilation is provided for the toilet-rooms. The tin-lined flues from these rooms are brought together in the attic and discharged through the roof by an electric-driven disc fan.

The building throughout will be provided with water service and modern plumbing. All drawing rooms and studies will have water service. Closets for janitors are provided on every floor in the toilet-rooms.

With the exception of the library and faculty room, the entire inside woodwork will be southern pine throughout.

Entering now from the southeast corner of the campus, one travels over the old diagonal walk for a distance of about one hundred feet, passing under the southeast portal into the arcade, the walls of which are of hammer-faced, light buff, Bedford limestone. The vaulting will be of brick with stone ribs, while the pavement under the arch will be of colored stone and brick.

To the right and to the left are windows guarded with artistic iron grills, to be made in the University shops. At suitable points hammered ironwork lanterns protect electric bulbs for lighting this public passageway at night. Turning to the right, one passes through one of the main entrance doorways to the ground floor of the East Wing into a broad entrance hall to one of the main stairways. Here

A sub-basement 20 x 40 feet extends along the south side of the steam laboratory. This will contain the weighing tanks for weighing water discharged from the surface condensers immediately above.

A room in the northeast corner will be used as a store room and pipe shop in connection with the laboratory.

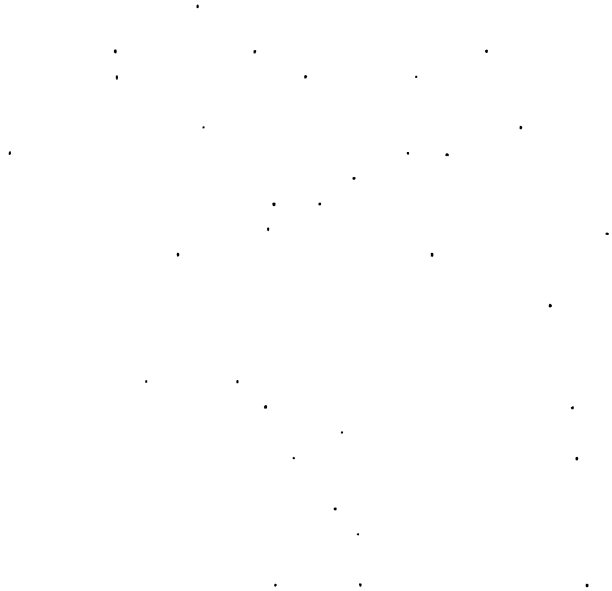
Extending to the north at the west end, is the boiler room in which will be erected the present 35 horse-power boiler for pressures of 200 pounds per square inch, and a new 100 horse-power boiler for pressures of 500 pounds per square inch. This new boiler will contain a superheater of a capacity to superheat the steam 200 degrees. The boilers will be connected directly to the chimney in one corner, and will also be provided with fan for induced draft. Space is provided in the boiler room for a gas producer plant for the production of gas for fuel purposes. A gallery 8 feet wide surrounds the boiler room, upon which will be placed the induced draft apparatus, feed water heaters and weighing tanks for boiler tests.

Returning to the arcade and passing into the South Wing of the building, one finds a portion of the space devoted to the electrical engineering department. Here are located two large electrical laboratories, one for direct current for heavy machinery, the other for alternating current for heavy machinery. Beyond these a series of rooms for research work, a calibration room, a photometry room for measurements on electric lamps, and a storage battery room.

Passing up to the second floor by one of the central stairways, which are situated in towers projecting from the northwest front of the main building, one comes to the second floor. On this floor immediately over the arcade and occupying the central portion, is located a beautiful room designated as the library. This apartment is 30 x 54 feet and is a feature of the building upon which the entire faculty united as most desirable. It will be wholly for the use of engineering students, where they can meet each other, read or study, and profitably pass the time intervening between lectures and other engagements. Three large windows face directly southeast and overlook the diagonal walk in that direction. At either end of the room will be large eight-foot fire places. Permanent seats in corners and tables and book alcoves, and such other furnishings as will make the room an attactive meeting place. The ceiling will be deep overhead open beam construction, the room finished in oak, with high wainscotting and red tile floor, all of which will give the room something of a scholastic atmosphere and tone.

Directly across the corridor, but still immediately over the archway will be the faculty room and secretary's office, these rooms, looking northwest and commanding an extended view clear across the campus by way of the diagonal walk.

The east side of the East Wing proper contains instructors' rooms, file rooms and two class rooms. The west side contains laboratory rooms for research work, and a room for compressed air work over the



found a large lecture room of the same size and immediately over the library, also a recitation room across the corridor. In the South Wing will be located a large drawing room, a recitation and lecture room, an instrument room and photographic dark room, and office for the professor of geodesy and surveying.

The fourth floor is devoted entirely to the work in stereotomy, mechanism and drawing. In the central portion of the building will be a large lecture room and office, separated by the usual corridor and corresponding in size to the room below. In the East and South Wings will be three large drawing rooms and one smaller drawing room. These rooms will receive their light from one directon only, that is, from a glass partition, lighted by an immense skylight situated over the corridor. The corridors themselves will all be brightly lighted from above and are especially adapted for the exhibition of drawings on their wall space. In addition to the above there are four class rooms. Thus, all the work in this department will be conducted on one floor, a specially economical and convenient arrangement.

From this outline sketch of the new building it will be seen that the Engineering Department may expect soon to be in possession of a building which will be a credit to the University and a distinct and valuable addition to the public property of the state: A building in which the people may well take a reasonable pride, and it is certainly to be hoped that they will avail themselves of all the opportunities it affords.

# DYNAMICS OF RECIPROCATING ENGINES

BY W. [illegible]

[illegible]

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If $P_1$ is taken to a scale, then the values of tangential and radial efforts may be measured directly.

It is more convenient, however, to determine the tangential effort

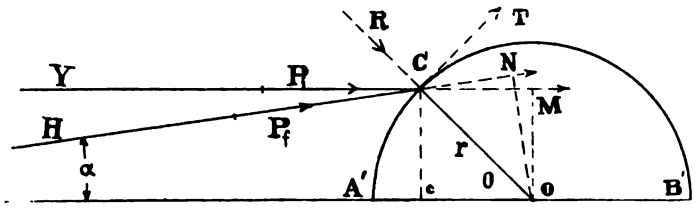



FIG. 1.

by taking from the center $O$ a perpendicular $OM$ upon the line of action of the force $P_1$ produced.

Denoting the tangential effort by $T_1$ and the radius of the circle by $r$, and taking moments about $O$, we have

$$T_1 \cdot r = P_1 \cdot \overline{O\,M} \ldots\ldots (1).$$

$$\text{whence} \quad T_1 = \frac{P_1 \cdot \overline{O\,M}}{r} \ldots\ldots (2).$$

If $r$ be taken to a scale $= P_1$, then $T_1 = O\,M$. Taking $Cc$ perpendicular to $A'\,B'$, we have $T_1 = O\,M = Cc = r \sin \theta$.....(3); or the tangential effort is represented by the sine of the crank angle, and is equal to it when $P_1 = r$.

If now the case of a connecting-rod is considered, let $H\,C$ represent the line of action of the force, making an angle $\alpha$ and with the line of centres. Produce $H\,C$ and from $O$ drop upon it the perpendicular $O\,N$. Let $P_f$ and $T_f$ denote the connecting-rod and the tangential efforts respectively; then as before

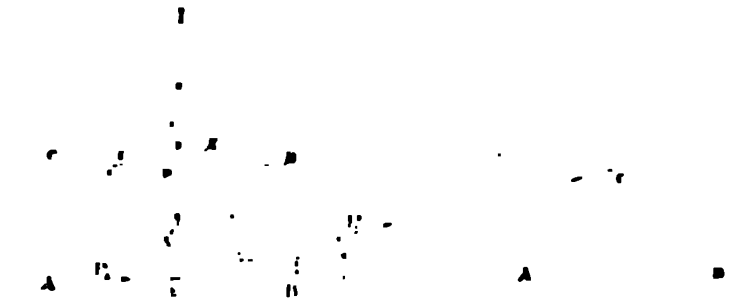
$$T_f \cdot r = P_f \cdot \overline{O\,N} \ldots\ldots (4).$$

$$\text{whence} \quad T_f = \frac{P_f \cdot \overline{O\,N}}{r} \ldots\ldots (5).$$

and if $r$ be taken $= P_f$, then $T_f = \overline{O\,N}$.

As will be seen the connecting-rod has the effect of increasing the tangential efforts in the first and fourth quadrants, and of decreasing these efforts in the second and third quadrants.

The value of $P_f$ may be found by multiplying by the secant of the angle $\alpha$, or $P_f = P_1 \sec \alpha \ldots\ldots (6)$.



it becomes easy to show by a diagram the tangential efforts for an entire revolution.*

In Fig. 3 let the upper part represent indicator diagrams in which $A\ B$ is the stroke, $A\ C\ D\ B\ A$, a diagram following full stroke, and $A\ C\ E\ F\ B\ A$, a diagram following part stroke. Consider first the diagrams shown by full lines. Divide the diagram into the usual ten equal spaces and erect in the middle of the spaces the ordinates numbered from 1 to 10. Each ordinate will represent the pressure against the piston for the space in which it stands, and the average of these ordinates will of course represent the average pressure against the piston for an entire stroke. On the diameter $A'\ B' = A\ B$, describe the crank circle, and project the ordinates as shown, cutting $A'\ B'$, also the circumference, in the points numbered from 1 to 10. Through these latter points of division draw the radial lines $s_1\ t_1$, $s_2\ t_2$ .....$s_{10}\ t_{10}$. With a radius $Os = A\ C =$ the uniform pressure for the stroke diagram, describe the semi-circle $s_1\ s_2$.....$s_{10}$. This last circle is called the *radial diagram of pressures* for full stroke. It amounts, of course, to taking the ordinates from the indicator diagram and laying them off from the centre $O$ on the radial lines which, to avoid confusion, have not been drawn from the centre to the circle $s_1\ s_2$ &c.; that is, $Os_1$, $Os_2$ &c., are taken equal to ordinates 1, 2 &c., of the indicator dingram.

If from the points $s_1\ s_2\ s_3$ &c., perpendiculars be dropped upon the line of centres $A'\ B'$, these perpendiculars will, as already shown, represent the tangential efforts for the corresponding crank positions with an indefinite connecting-rod.

Now take these perpendiculars and lay them off outside the crank circle, considered as a base circle; that is, take $1t_1$, $2t_2$, $3t_3$....$10t_{10}$, equal respectively to the perpendiculars upon $A'\ B'$ from $s_1$, $s_2$....$s_{10}$, and connect the extremities by the curve $A'\ t_1\ t_2$....$t_{10}\ B'$; this line is known as the *curve of tangential efforts*, and shows at a glance the turning effort for all positions of the crank from the beginning to the end of one stroke. The curve for the return stroke with an infinite connecting-rod [not shown] would be identical with that for the forward stroke.

Considering the diagram in which steam follows with full pressure through $CE$ and expands through $EF$, the radial diagram becomes $s_1\ s_2\ s_3\ s_4\ s'_5$....$s'_6$....$s'_{10}$, and the sines or perpendiculars being drawn and laid off as before give the tangential diagram $A'\ t_1\ t_2\ t_3\ t_4\ t'_5\ t'_6$.... $t_{10}\ B'$.

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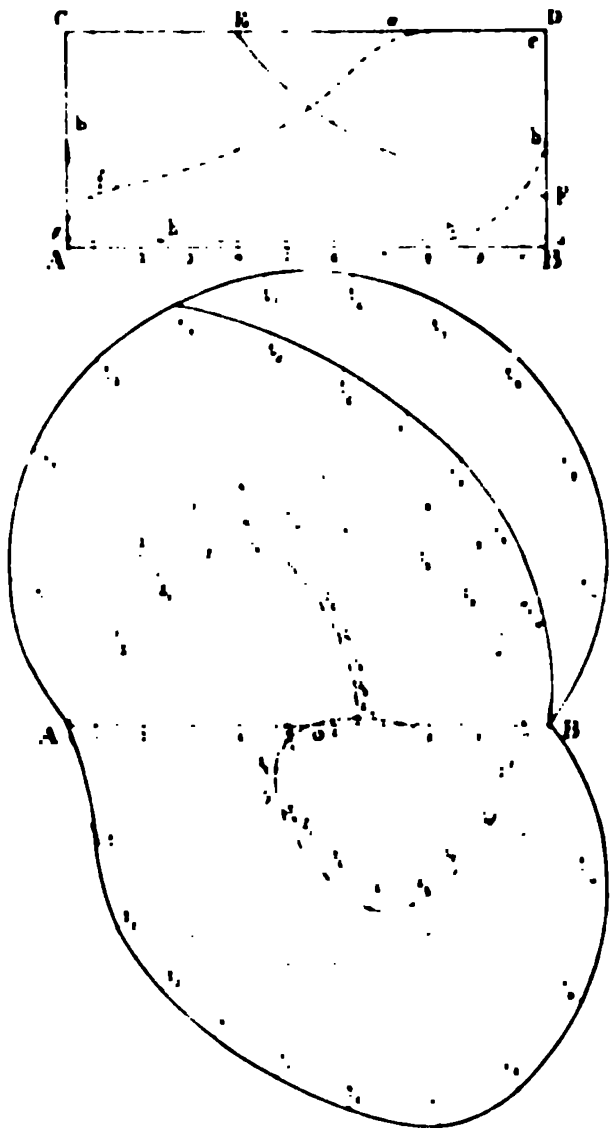
* The radical and tangential diagrams used in this paper were originally presented by Mr. Arthur Rigg, in England, in 1870. See "A Practical Treatise on the Steam," by Rigg.


C
E
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B

The indicator diagrams thus far considered are ideal, and are never fully realized in practice. The dotted diagram shown for the return stroke is modified to represent more closely actual practice, the corners at $e$, $f$, $g$ and $hb$ being rounded for practical reasons: the back-pressure line $ga$ lies above $AB$ by an amount equal to the back-pressure. It will be evident that as steam pushes the piston on one side with a pressure varying, as shown by the line $c\ e\ f\ g$, the piston pushes or expels the steam from the cylinder on the other side with a pressure varying, as shown by the line $a\ h\ h'\ b'$; therefore, the *useful* pressure will be the difference between the ordinates of these lines, becoming negative where they cross at $f$. In the lower half of the crank circle, then, construct the radial diagram $s_{10}\ s_9 \ldots s_1$ by taking the difference of these pressures. Where the expansion line $eg$ crosses the compression line $h'b'$, the pressures on the two sides of the piston are equal, and the radial diagram passes through the center $O$. From this point to the end of the stroke the back pressure is greater than the forward pressure, and the radial diagram continues as shown.

By erecting the perpendiculars and laying off outside of the base circle, as before, we get the tangential diagram $B'\ t_{10}\ t_9 \ldots t_1\ A'$. Between $t_2$ and $t_1$ it passes inside the base circle, showing that instead of a rotational effort driving the crank, the crank drives or pulls the piston. The diagram, then, shows at a glance the effect of efforts on the piston in turning the crank: and all being constructed to a scale, quantities may be measured with as much accuracy as the original indicator diagrams.

If preferred a straight line may be used instead of the base circle, the tangential efforts being laid off on ordinates spaced the same as on the circle, at right angles to the base line.

The *mean* tangential effort may be found by dividing the tangential diagram into equal spaces on the base circle, drawing radial ordinates, and averaging the same as the indicator diagram; or it may be found as follows: The useful work done on the piston is of course equal to the useful work done on the crank-pin. While the piston travels the length of its stroke $A\ B$, the crank-pin travels the length of the semicircle on $A'\ B'$.

$$\text{This latter length} = A'\ B' \frac{\pi}{2} = A\ B \frac{\pi}{2} = 1.5708\ A\ B \ldots . (9).$$

Let $p$ equal the mean effective pressure per sq. inch against the piston for a stroke, found by averaging the ordinates of the indicator diagram and multiplying by the scale of the diagram, and $t$, the tangential effort corresponding to $p$, then

$$p \cdot A\ B = 1.57\ A\ B \cdot t \text{ whence } t = \frac{p}{1.57} \ldots . (10).$$

The ... effective pressure and the ... mean tangential ... of crosses to ... by means of ..., and ... by the area of ...

... may be ... from the base circle to the proper ... by ... from centre of the circle as ... Figs. ... and ... show these ... the ... outside ... inside of the circle should be ... with a light pencil.

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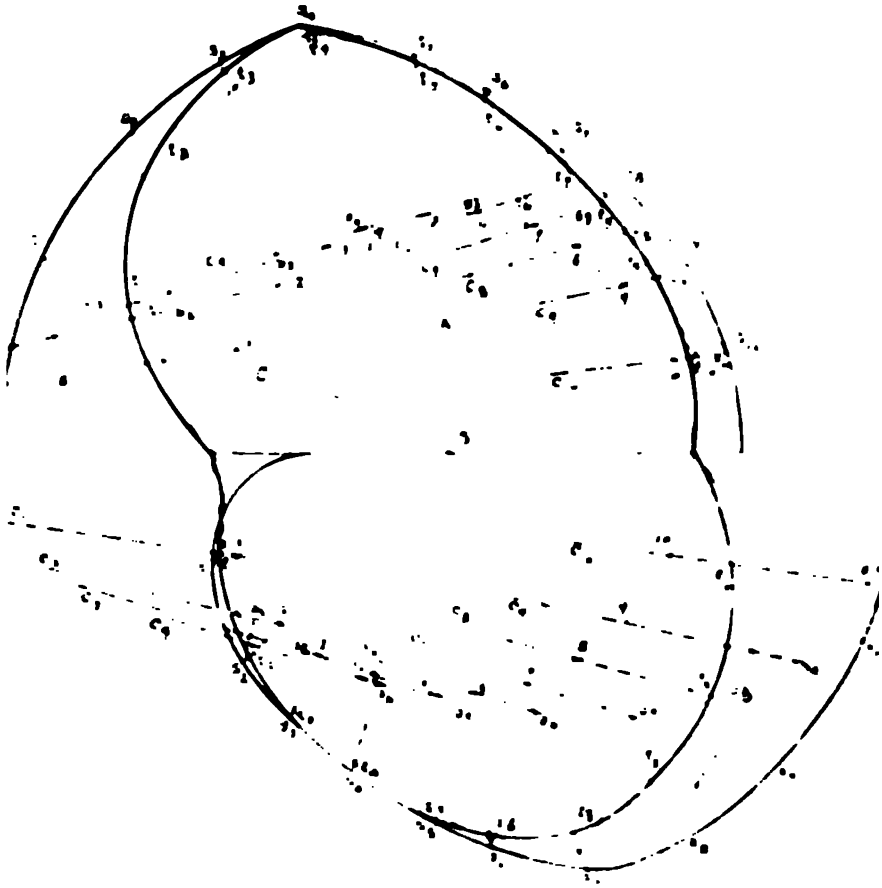


Fig. 4

angularity of the connecting-rod. The construction is as follows: $C_1 1$, $C_2 2$, $C_3 3$.....$C_{10} 10$ are positions of the connecting-rod corresponding to the crank positions *1, 2, 3....10*, $C$ represents a point on the radial diagram as in Fig. 3; through $C$ draw $CA$ parallel to the corresponding crank position, from the center $B$ let fall a perpendicular on $CA$. This perpendicular, as already shown, will be equal to the tangential efforts. The following construction gives less confusion; from the point *1* draw the radius $1S$, equal to the pressure of the piston and equal to $CB$. From the point $S$ let fall perpendicular on the connecting-rod position $C_1 1$ cutting it in $O_1$. Now since the two triangles $ACB$ and $1S_1O_1$ have two sides parallel and one side equal, the other sides are equal, hence $AB$ equals $S_1O_1$ equals the tangential effort. In a similar manner we find the tangential efforts $S_2O_2$, $S_3O_3$, $S_4O_4$.....$S_{10}O_{10}$. These tangential efforts are laid off from the base circle giving the curve $t_1, t_2, t_3 \ldots t_{10}$. In the diagrams that follow the piston pressures have been laid off from the centers of the crank circles. The same construction follows for the return stroke shown in the lower half of the circle.

Thus far only a single engine has been considered; but the same construction may be applied to an engine with any number of cylinders, care being taken to reduce all of the diagrams to the same scale before combining, considering not only the scale of the indicator diagrams, but also the relative sizes of the cylinders. For example, take a two-cylinder compound engine with the condensing cylinder twice the volume of the non-condensing cylinder. Let the scale of the indicator diagram from the first be 20 lbs. to the inch, and from the latter, 60 lbs. to the inch; then the tangential efforts of the non-condensing cylinder will need to be multipled by the fraction 3-2 in order to reduce both to the condensing cylinder. Thus the area of condensing cylinder $\times$ combined tangential ordinate will equal total turning effort. This may be conveniently done by the use of proportional dividers. In referring the tangential diagram to a common base circle preparatory to combining, care should be taken that no error be made in the relative positions of the diagrams.

Fig. 5 shows a pair of diagrams worked up for the U. S. S. Quinnebaug.

These engines are two-cylinder compound, the dimensions being 42 ins. and 64 ins. diameter, and 42 ins. stroke. The condensing cylinder is 90° ahead of, or 270° behind, the non-condensing cylinder. The diagrams represent the engines doing 1102 I. H. P., or 590 for the non-condensing, and 512 for the condensing cylinder; 61 revolutions were made per minute, with a boiler pressure of 78 lbs. per sq. in., and a vacuum of 19 ins. The scales of the diagrams were 40 and 20 lbs. to the inch, but as they have been reduced to two-thirds full size, the scales have been marked 60 and 30 lbs. to the inch. The circular and tangential diagrams were made separately and then combined, as shown in the figure. Light full lines indicate the non-

condensing, and dotted lines the condensing cylinder diagrams, the heavy line the combined diagram. The circles of mean tangen-

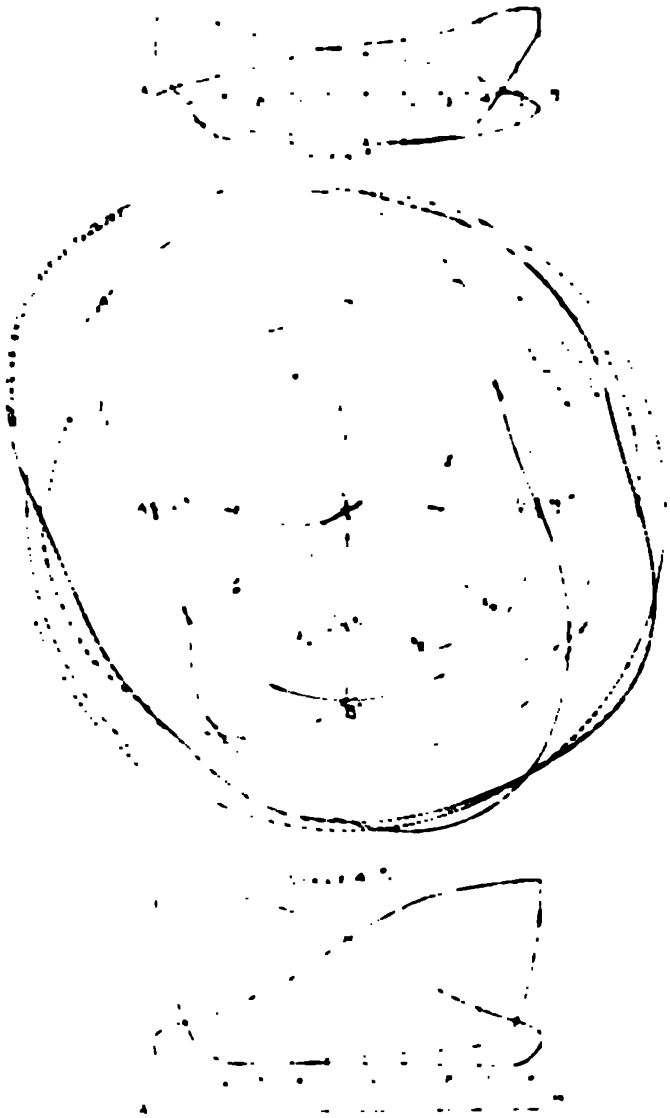


FIG. 4.

tial efforts are marked as shown. The hatched portions outside and inside of the combined mean tangential effort circle show the variation of the tangential efforts. The diagram will be clear without further explanation, and it will be apparent that the maximum tangential effort for which the shaft and crank must be designed may be easily located, and measured with accuracy. Frequently, surprising irregularities are found by the use of the diagrams as explained; but more surprising will the irregularities be found when the effect of acceleration is considered.

*Second, The Efforts as Affected by Acceleration of the Reciprocating Parts.*—Thus far only the tangential efforts have been considered, and these unaffected by disturbing influences other than those due to the angularity of the connecting-rod. We will next consider the effects of acceleration and retardation of the reciprocating parts.

As before, first consider an engine with an infinite connecting-rod, and in Fig. 6 let $O$ be the center of a crank circle described on $A'B'$ as a diameter. Take the crank $OC$, making any angle $\Theta$ with $A'B'$, and draw $VC$ and $CV$ to represent direction of piston and tangential efforts respectively. Erect the perpendiculars $VM$ and $Cc$. Let $V$ = velocity of crank-pin, and $v$ = velocity of piston. This is, then, a case of simple harmonic motion. If

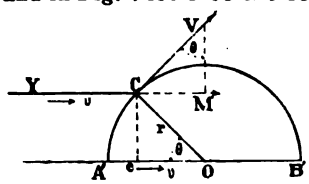


FIG. 6.

$V$ = $CV$ = uniform tangential velocity of crank-pin, $CM = V \sin \Theta = v$ = variable velocity of piston; and if $r$ be taken equal to $V$, then $Cc = CM = v$. If $v = CM = V \sin \Theta$ = velocity of piston,

$\frac{dv}{dt} = V \cos \Theta \frac{d\Theta}{dt}$ = the acceleration. But $Vt = r\Theta$, and $\frac{d\Theta}{dt} = \frac{V}{r}$,

whence $\frac{dv}{dt} = \frac{V^2}{r} \cos \Theta = y$....(11).

From the figure $cO = r \cos \Theta$ whence $\cos \Theta = \frac{cO}{r} = \frac{r - A'c}{r} = \frac{r-x}{r}$,

where $x$ = distance piston has moved from beginning of stroke.

Therefore, $y = \frac{V^2}{r^2}(r-x)$....(12), the equation of a straight line.

For $x = 0$, $y = \frac{V^2}{r}$, for $x = r$, $y = 0$, for $x = 2r$, $y = -\frac{V^2}{r}$, showing that this line of acceleration at the beginning of the stroke is above, at the centre crosses, and at the end is below, the horizontal, as shown in the lower half of Fig. 7. The values of the acceleration may be found graphically as follows:

[illegible] take the circle with diameter divided into equal spaces, and numbered as before. Erect ordinates cutting circle in points [illegible] and from these points draw the horizontals $c_1 p_1$, $c_2 p_2$, [illegible]. These horizontals, or cosines, will be *proportional* to the accelerations corresponding to the different crank positions; if the radius of the crank pin be taken equal to the radius, then these cosines will be equal to the accelerations, in which case the lower half

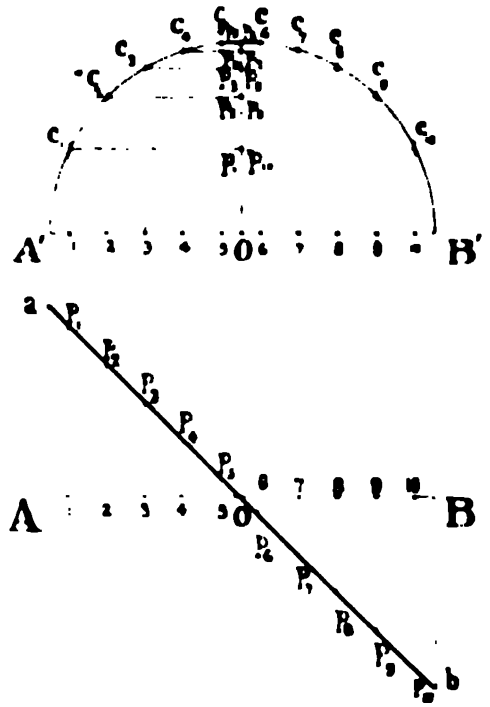



Fig. [illegible]

of the figure may be used as before by transferring with the dividers these cosines to the [illegible] from the line A B as shown. The [illegible]

I [illegible] H [illegible]

in the expression [illegible] is the weight [illegible] and

in the expression [illegible] is the weight [illegible] which in our case we propose to be the weight of the reciprocating parts. In

practice it is more convenient to reduce this weight to the equivalent weight per square inch of piston area, or $w = \frac{W}{A}$, where $A$ = area of piston. In ordinary cases the value of $w$ varies from 2.5 lbs. to 5 or 6 lbs. As an example take an engine 10 ins. diameter, and 12 ins. stroke, making 300 revolutions per minute, with a value of $w = 3$ lbs.

$V = \frac{300 \times \pi}{60} = 15.708$ ft. per second, and $y = \frac{3 \times \overline{15.7}^2}{32.2 \times \frac{1}{4}} = 45.9$ lbs., or a pressure of 45.9 lbs. per sq. inch is required to start the reciprocating parts from rest, assuming no friction; and an equivalent pressure is given out at the end of the stroke.

If $w = 2$ lbs., the pressure for acceleration becomes $\frac{2}{3} \times 45.9 = 30.6$ lbs. per sq. inch. If the revolutions are 200, the pressure becomes $(\frac{200}{300})^2 \times 45.9 = 20.4$ lbs. per sq. inch, and with 100 revolutions the pressure becomes $(\frac{100}{300})^2 \times 45.9 = 5.1$ lbs. per sq. inch.

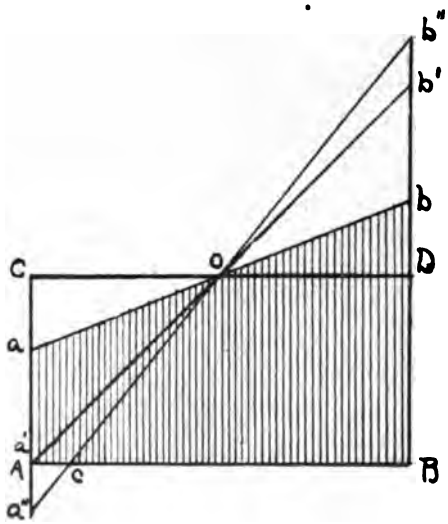
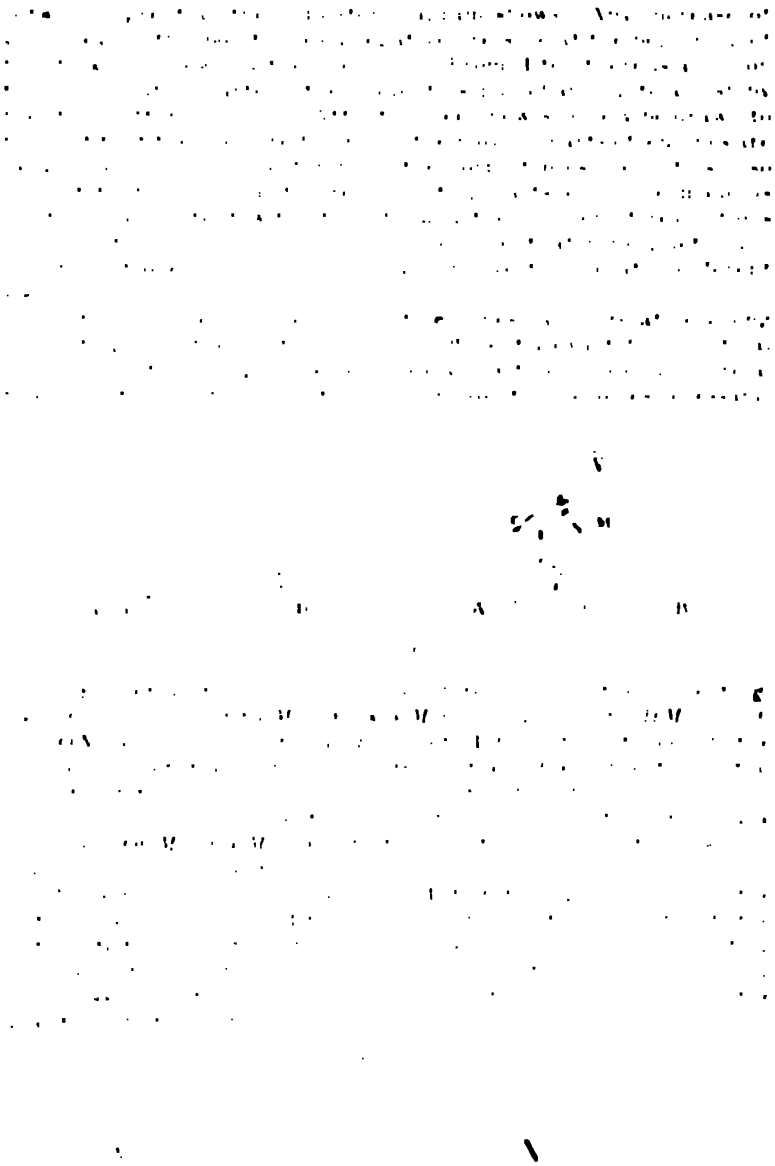



FIG. 8.

In Fig. 8 let $A\,C\,D\,B\,A$ be indicator diagram following full stroke. Take $C\,a$ equal to the pressure required for acceleration at the beginning of the stroke $= D\,b$ the equivalent pressure due to retardation at the end of the stroke. Draw $a\,b$ cutting $C\,D$ in $O$. Then the effective pressure against the piston at the beginning of the stroke is $A\,C - C\,a = A\,a$, and at the end of the stroke, $B\,D + D\,b = B\,b$, while at the middle of the stroke it remains unchanged. During the first half of the stroke work represented by the trian- $C\,O\,a$ has been done on the reciprocating parts by accelerating them, and during the second half, work represented by the equal triangle $D\,O\,b$ has been done *by* the reciprocating parts in retarding them, the *total* work remaining unchanged.

With a higher speed let $C\,a' = D\,b' =$ the pressure for acceleration and retardation. Then at the beginning of the stroke there is no effective pressure against the piston, and at the end the pressure



But $\Phi = a + \theta$, therefore, $\sin \Phi = \sin a \cos \theta + \cos a \sin \theta$....(*15*).

Substituting the values of $\sin a$ and $\cos a$ from (*14*), we have

$$\sin \Phi = \frac{r}{l} \sin \theta \cos \theta + \sqrt{1 - \frac{r^2}{l^2} \sin^2 \theta} \cdot \sin \theta \ldots . (16).$$

Substituting in (*13*) and dividing by (*14*),

$$v = V \left\{ \frac{\frac{r}{l} \sin \theta \cos \theta + \sqrt{1 - \frac{r^2}{l^2} \sin^2 \theta} \cdot \sin \theta}{\sqrt{1 - \frac{r^2}{l^2} \sin^2 \theta}} \right\} \ldots . (17).$$

$$= V \left\{ \sin \theta + \frac{\sin \theta \cos \theta}{\sqrt{\frac{l^2}{r^2} - \sin^2 \theta}} \right\} \ldots . (18).$$

Comparing this with the equation for the relative velocities with an infinite connecting-rod, $v = V \sin \theta$, we see that the additional effect of a finite rod is determined by the fractional term which is expressed with only the crank angle as a variable.

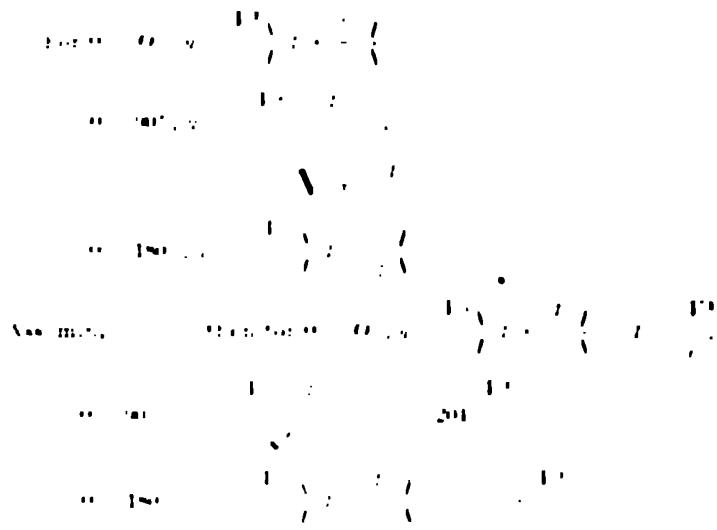
For the acceleration we have

$$y = \frac{dv}{dt} = V \left\{ \cos \theta + \frac{\left\{ \frac{l^2}{r^2} - \sin^2 \theta \right\} \cos 2\theta - \sin^2 \theta \cos^2 \theta}{\left\{ \frac{l^2}{r^2} - \sin^2 \theta \right\}^{\frac{3}{2}}} \right\} \frac{d\theta}{dt} \ldots . (19).$$

But $Vt = r\theta$, and $\frac{d\theta}{dt} = \frac{V}{r}$; whence

$$y = \frac{V^2}{r} \left\{ \cos \theta + \frac{\left\{ \frac{l^2}{r^2} - \sin^2 \theta \right\} \cos 2\theta - \sin^2 \theta \cos^2 \theta}{\left\{ \frac{l^2}{r^2} - \sin^2 \theta \right\}^{\frac{3}{2}}} \right\} \ldots . (20).$$

An expression differing from that secured for the acceleration with an infinite rod by the fractional term alone.



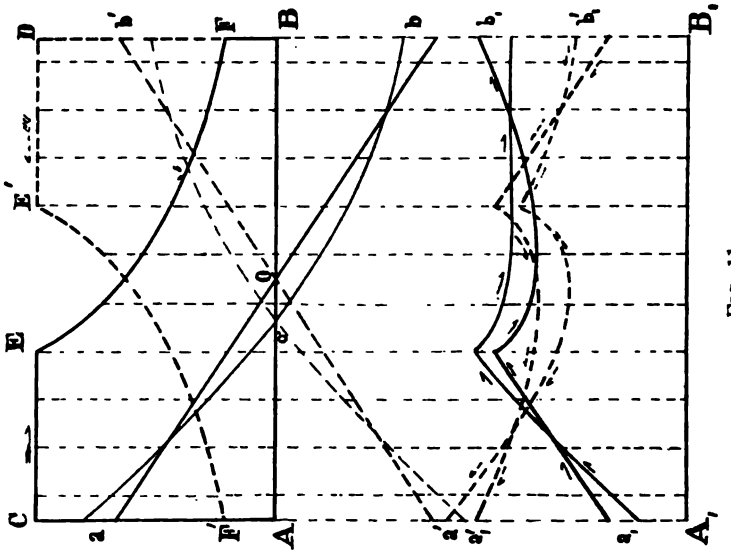


FIG. 11.

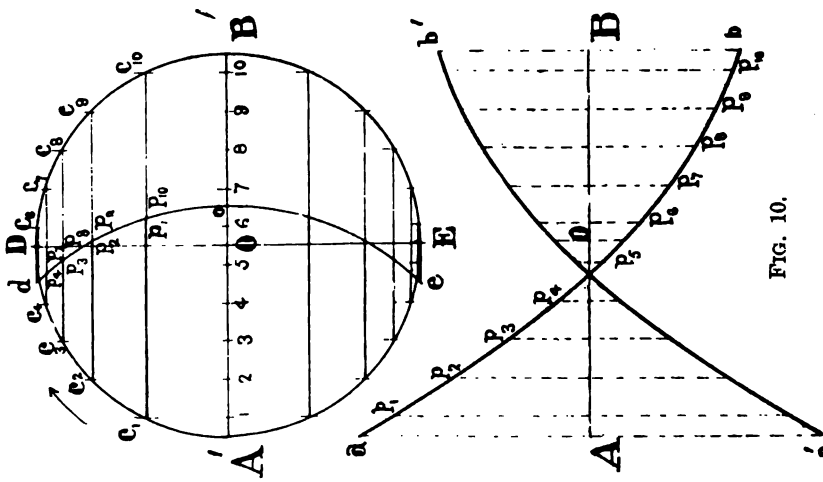
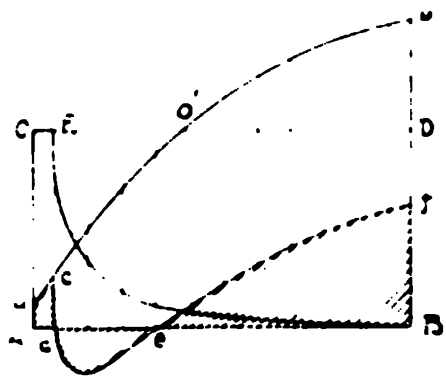


FIG. 10.


C
E
O'
D
C
e

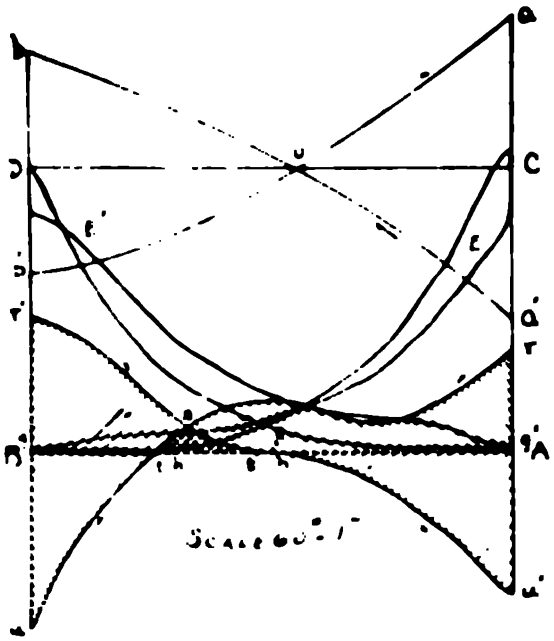
The indicator diagrams in Fig. 13 were taken when the engine was running empty. The revolutions were 240 per minute. $A$ is the head end, and $B$ the crank end. The spring used was 40 lbs. to the inch, but as the diagrams have been reduced to two-thirds full size the scale is marked 60 lbs. to the inch. The pressure per sq. inch to start the reciprocating parts from rest is, for an infinite rod $= \frac{w\ V^2}{g\ r}$.

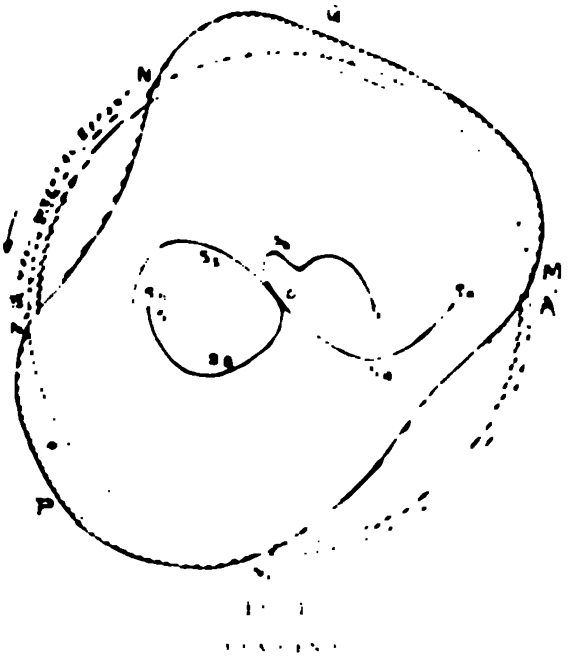
$w = 2.86$ lbs. $\quad r = 8$ ins. $= \frac{2}{3}$ ft.

$V = \frac{240}{60} \times 2 \times \frac{2}{3} \times \frac{22}{7} = 16.76$ ft. per sec.

$$y = \frac{2.86 \times 16.76^2}{32.2 \times \frac{2}{3}} = 37.51 \text{ lbs.}$$

To this quantity, for a rod 51 ins. long and a crank 8 ins. long must be added $\frac{8}{51} \times 37.51 = 5.88$ lbs. And $37.51 + 5.88 = 43.39$ lbs., required to start the reciprocating parts from rest, and $37.51 - 5.88 = 31.63$ lbs. to bring them to rest again at the end of the stroke. The pressure for the crank end diagram would be a little greater as the area of the piston-rod decreases the area of the piston; but it may without serious error be considered the same. A circle may now be described with a radius $= 37.51$ lbs. to a scale of 60 lbs. to the inch, as in Fig. 10, and the points $d$, $o$, $e$ found by taking $Oo = Dd = Ee = 5.88$ lbs. to the same scale, and describing the arc of the circle $d\ o\ e$. The diameter and circumference being divided the same as the indicator diagram, the horizontals may be drawn and the distances $A'\ o$, $c_1\ p_1$.. ....$C'_{10}\ p_{10}$, $B'\ o$ transferred and laid off on the ordinates (not drawn) from the line $C'\ D$. A comparison of the forward pressure line of the diagram $E$, of the back pressure line of $E'$, and of the acceleration line $a\ b$, gives us the line of effective piston efforts $r\ s\ t\ u$, referred to the line $A\ B$. For the return stroke, in the same way, may be found the line $r'\ s'\ t'\ u'$. On both strokes the piston efforts become negative at the points $t$ and $t'$. The ordinates of the lines $r\ s\ t\ u$ and $r'\ s'\ t'\ u'$ may now be transferred to the lower figure giving the radial diagrams $s\ s_1\ s_6\ O\ s_9\ s_8$ and $s_0\ s_8\ O\ s_2\ s_5$ for the forward and return strokes respectively. From these radial diagrams the tangential diagrams $A'\ M\ Q\ N\ B'$ and $B'\ N'\ P\ M'\ A'$ are found. The mean tangential effort circle may be found by formula, or by averaging ordinates, as already explained. An inspection of the figures shows a *positive* turning effort from $A'$ to $N$, and a *negative* turning effort from $N$ to $B'$. On the return stroke it is positive from $B'$ to $M'$ and negative from $M'$ to $A'$.





Figs. 14 and 15 show results for the engine under normal load making 235 revolutions per minute. In Fig. 14 the acceleration lines are referred to $A\ B$, and the lines of effective piston efforts to a line below (not lettered). The radial diagrams of effective piston efforts, and the tangential diagrams in Fig. 15 will be clear from previous constructions.

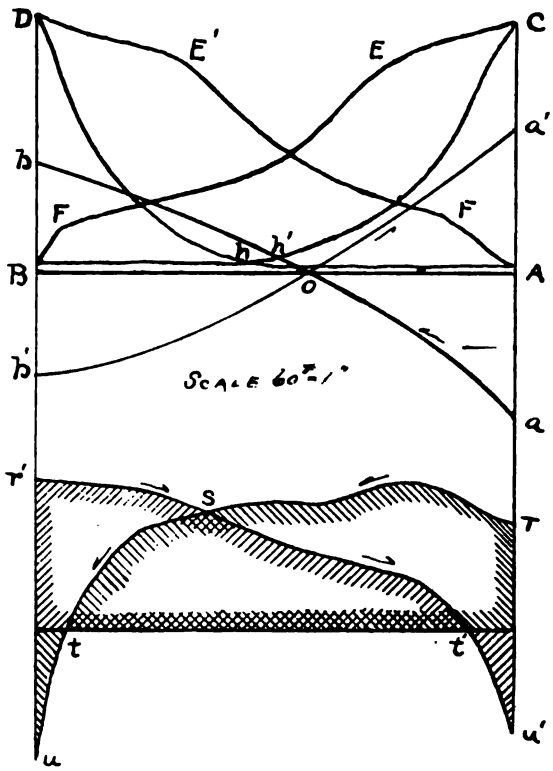
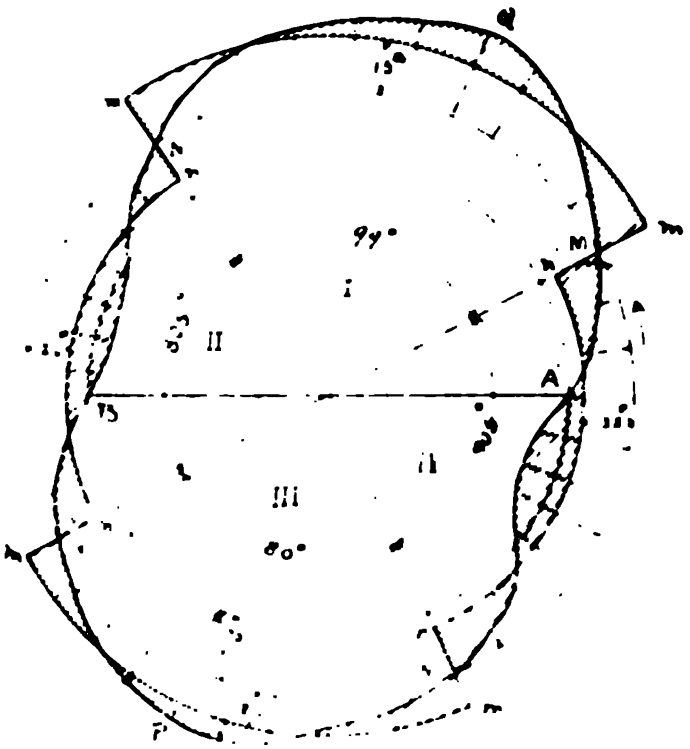



FIG. 14.

The mean effective pressure found by averaging the two indicator diagrams is 26.94 lbs.; and this multiplied by twice the stroke equals the work done in one revolution by one sq. inch of piston area, and it also equals the work done in one revolution on the crank-pin; or

$$26.94 \times 2\ \overline{AB} = pt \times \overline{A'B'};\ \text{whence } pt = \frac{26.94}{1.57} = 17.16 \text{ lbs.},$$

for the mean tangential effort. This quantity laid off to the scale of 60


90°
M
A
II
I
III
II

lbs. The angle is $\frac{99}{360} \times 2\pi = 1.73$, and the crank radius is $\frac{2}{3}$ of a foot; therefore the excess is $15 \times 1.73 \times 0.67 = 17.3$ ft.-lbs. per sq. inch.

In the same way we may find the excess or deficiency for other fractions of the revolution, when all may be grouped in a table as follows:

| | | Power. | Resistance. |
|---|---|---|---|
| I. | Excess through 99° | 17.30 | |
| II. | Deficiency " 80.5° | | 11.80 |
| III. | Excess " 90° | 9.06 | |
| IV. | Deficiency " 90.5° | | 14.54 |
| | | 26.36 | 26.34 |

The work for one revolution is equal to $17.16 \times 2\pi \times \frac{2}{3} = 71.91$ ft. lbs. per sq. inch. Therefore, the excess of power, or of resistance, in one revolution is $\frac{26.35}{71.91} = 0.366$ of the whole energy; and this fluctuation must be provided for by the fly-wheel. It is customary, however, to provide a fly-wheel that will care for the *maximum* fluctuation of energy, and this will of course give lesser variations of speed for the lesser fluctuations of energy.

For instance, during the fractions of the revolution numbered I and II, the excess of power is 17.30 ft. lbs. and the total energy per sq. inch of piston for that portion of a revolution is $\frac{71.91}{2} = 35.95$ ft. lbs.; therefore, the excess of power for one-half revolution is $\frac{17.30}{35.95} = 0.481$ of the total energy for one-half revolution. To design the fly-wheel for this fluctuation will give closer regulation in other parts of the revolution. The area of the piston equals 95 sq. inches, and $95 \times 17.30 = 1643.5$ ft. lbs. for the total excess, which we will call $\Delta$ E.

In practice we may consider the *rim* of the fly-wheel as the governing weight, neglecting the arms and hub.

If, then, a fly-wheel rim of weight $W$ change in velocity from $V_1$ to $V_2$ ft. per second, the energy represented by the change will equal $\frac{W}{2g}(V_2^2 - V_1^2) = \frac{W}{2g}(V_2 + V_1)(V_2 - V_1) = \Delta$ E. But $V_2 + V_1 = 2V =$ twice the mean velocity, and $V_2 - V_1 =$ the difference between the greatest and least velocity $= \frac{V}{m}$; therefore $W = \frac{2g\,\Delta\,E}{2V \times \frac{V}{m}} = \frac{mg\,\Delta\,E}{V^2}$, the usual Rankine formula.

[illegible]

## THE RIVER AND HARBOR WORKS AND THE CIVIL ENGINEER.

HENRY CLAY RIPLEY, '70, MEM. AM. SOC. C. E.

There is probably no appropriation bill passed by Congress that has greater interest for the public in general than that for the improvement of our river and harbors.

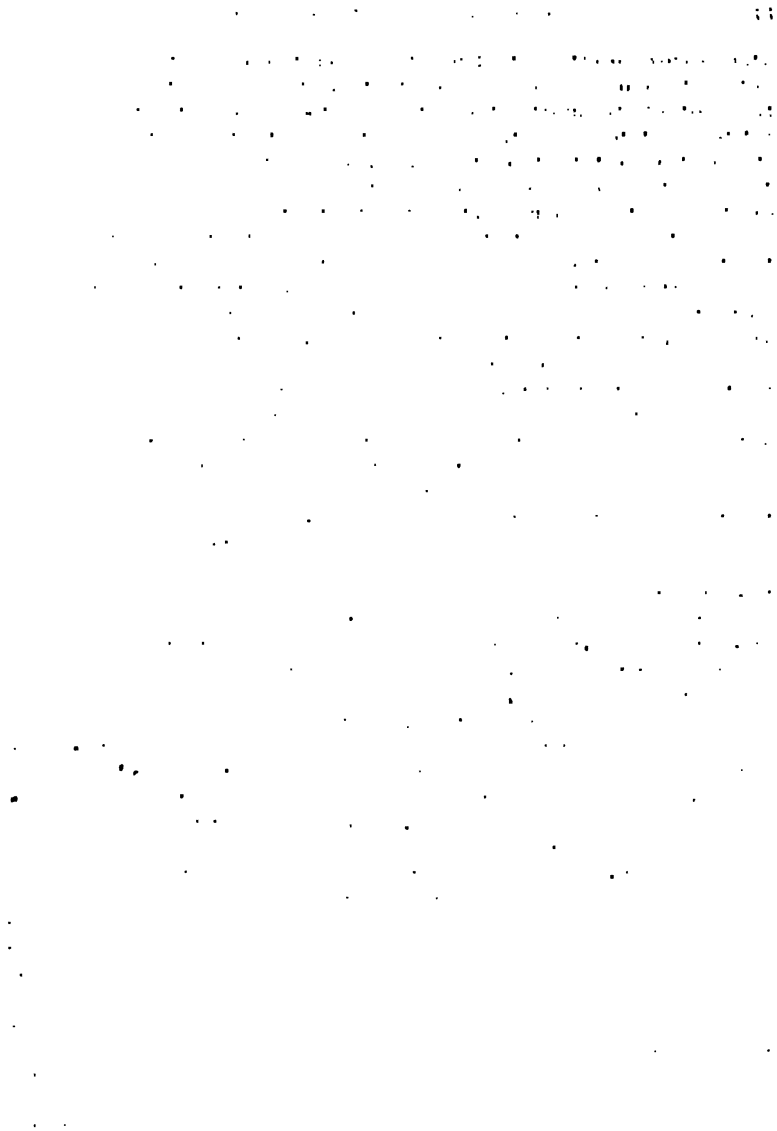
The present Rivers and Harbors bill which has just passed the senate, carries an aggregate of about $70,000,000. The bill of the last congress aggregated more than $60.000,000 and, since a bill is passed on an average once in two years, the annual expenditure for river and harbor work is in the neighborhood of $30,000,000. This immense sum is being expended annually upon works of a purely civil nature, works in which the civil engineers of this country are eminently qualified both by education and experience to execute, and yet it may truthfully be said that, as a class, the civil engineers take less interest in these appropriations than does the general public.

It is difficult to understand that such a condition can exist and it is believed that it can only be accounted for by the fact that the civil engineers do not appreciate the fruitful field that would be open to them professionally, and the great benefit and economy that would result to the government by the inauguration of a different state of affairs from that which now exists.

A brief acount of the policy under which these works are conducted and some of the efforts which have been made to remedy its defects will lead to a clearer understanding of the situation and will pave the way to the intelligent consideration of some suggestions which it is purposed to make.

Under the present policy the law provides that the money appropriated for the works shall be expended under the direction of the Secretary of War and the supervision of the Chief of Engineers of the Army. The law also provides that the work shall be done by contract, awarded to the lowest responsible bidder after due advertisement, except in a few cases where a deviation from this regulation is permitted.

The conduct of the work is, therefore, under military rule and the regulations are those adapted to the military service. While it is true that there is a considerable number of civil engineers engaged on these works; they occupy subordinate positions and can only attain to the rank of assistant engineer and under no circumstances, no matter what qualifications they may possess, can they succeed to independent charge of work.



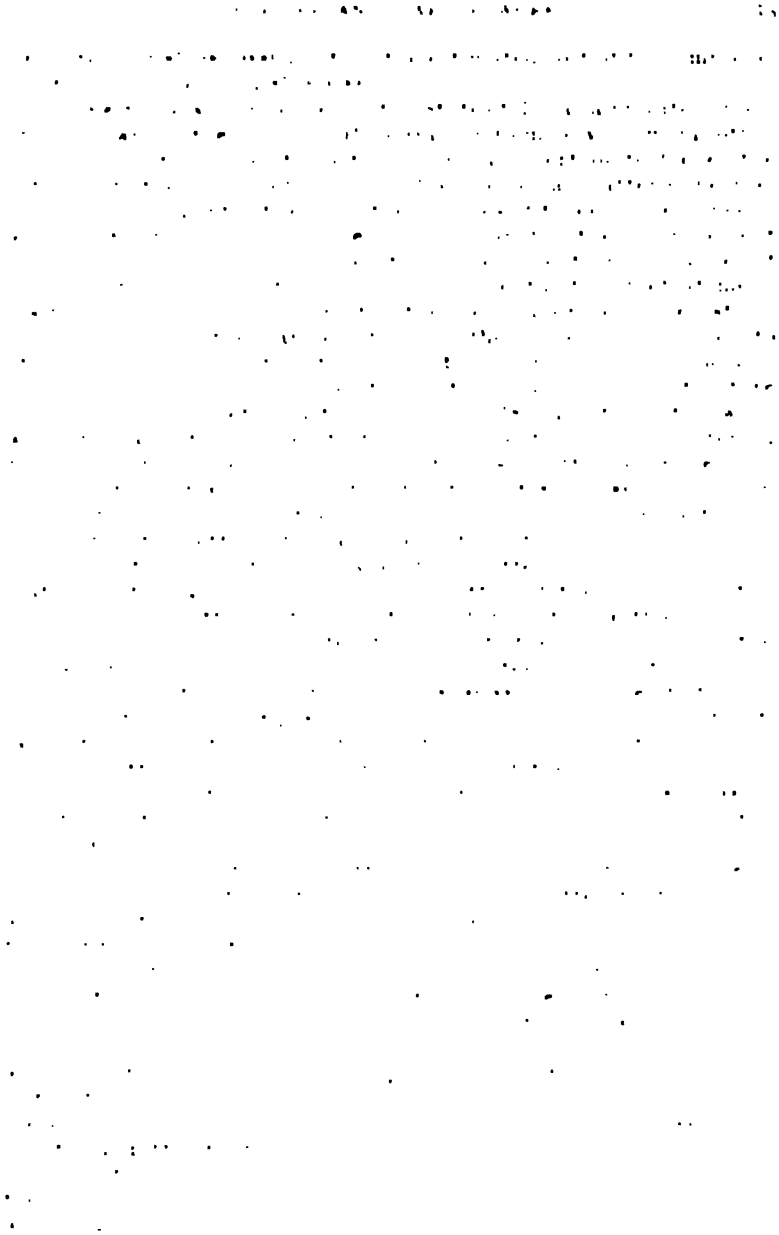
that a compromise was finally effected by which Mr. Eads accepted a contract from the government to improve South Pass instead of South West Pass, for the sum of $5,250,000 for a channel 26 feet deep and 200 feet wide, and he agreed to maintain this channel for twenty years for the additional sum of $100,000 annually. This work was completed in five years and the channel was maintained for twenty years, greatly to the benefit of commerce and the advantage of the government.

This contract with Mr. Eads was regarded by the army engineers as an innovation upon the rights and prerogative of their corps and at first some considerable friction was developed between the Chief of Engineers and Mr. Eads which resulted in the Chief of Engineers being relieved from all control of the inspection of that work. This duty, however, was restored to his successors and no further trouble was experienced.

Under the River and Harbor Acts of 1894 and 1896, Mr. C. P. Goodyear, a lawyer, was authorized to deepen the outer Bar of Brunswick, Ga., by a method of his own, for a sum of money, depending on the results secured, aggregating less than 10 per cent. of the estimated cost of the approved plan: which latter consisted of two long jetties extending from the shore across the bar. Mr. Goodyear completed his contract in 1899, having secured a channel across the bar with a minimum depth of 25 feet and a minimum width of 150 feet and for which he has received an aggregate sum of $220,000. This experiment has demonstrated that jetties would not have been economical at that place and which, it is estimated by the officer now in charge of that work, would cost the sum of $2,829,608.

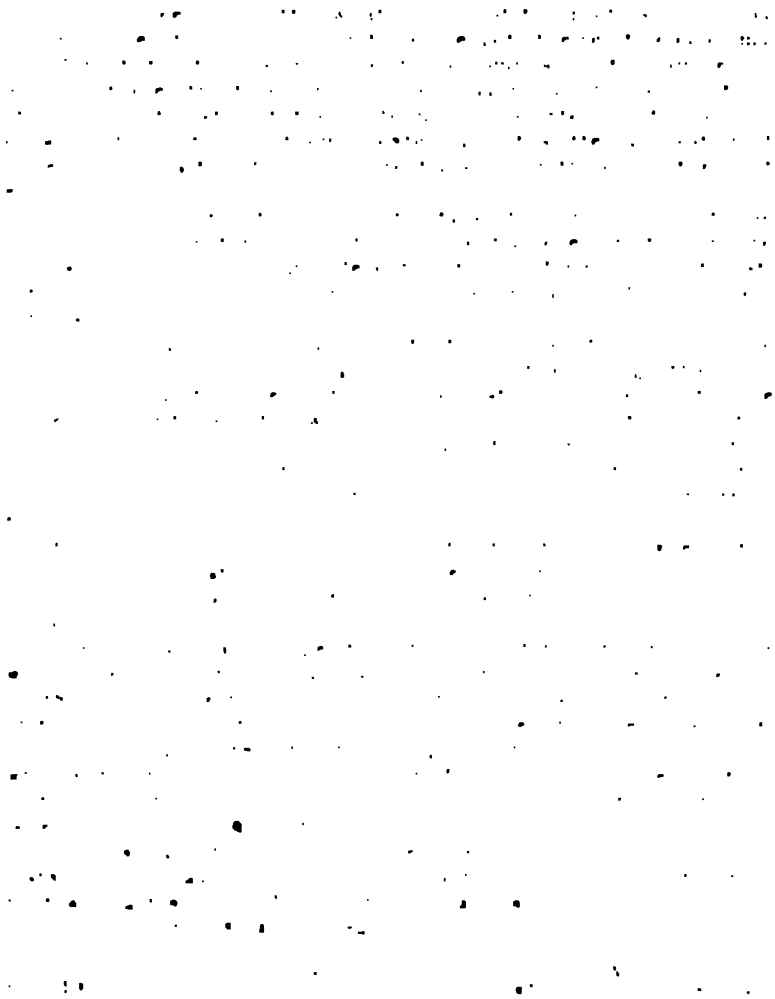
The army officers in charge of the inspection of this work were apparently much prejudiced against Mr. Goodyear's methods of deepening the channel and it was not until they were relieved of this duty and an official of the Coast and Geoditic Survey assigned to it, that he was able to get a certificate for results obtained which the law required before payments could be made to him. The delay in securing payment for results obtained and other expenses not strictly pertaining to the work itself, made this contract unprofitable to Mr. Goodyear, but the government reaped the benefit and a valuable lesson was taught.

In 1899 the Secretary of War transmitted to Congress a plan for the improvement of South West Pass, Mississippi river, with a view of securing a navigable channel of adequate width and of 35 feet depth, the estimated cost of which was $13,000,000. When this matter was being considered by the committees of the House and Senate, Prof. L. M. Haupt submitted a proposition to secure a channel of the same dimensions and guarantee the results for $6,000,000. The matter was, therefore, referred back to the War Department for revision with the result that an entirely different plan was submitted signed to secure the same result but at an estimated cost of $6,000,-



have been devised had been adopted in each particular case. What more certain way can there be of securing the best plan than by open competition? Results are what the government is after. Let the Secretary of War be authorized to solicit bids for securing the results desired and then the person who can back up his plan with a guarantee of results will be the one to get the work. Such a policy would bring to the service of the government the best engineering talent in the country, without cost, and would insure the utmost possible economy in its expenditures for river and harbor improvements. There should moreover be no objection to this policy from those now in charge of the works for there would be no change in their control or supervision, and on the other hand the civil engineers of the country would be put in possession of a clientage of immense value and to which they are rightfully entitled.

# COMPARATIVE ECONOMY OF STRUCTURES



The second term of the series is the sum that will amount to $100 in $n$ years at $r$ per cent. per annum, compound interest, or the *present worth* of $100 $n$ years hence. The third term is the same for 2 $n$ years, and so on.

*Examples.*—What outlay would be justified to make a structure last 100 years instead of 10 years, at 6 per cent. compound interest per annum?

$$C = \$100 + \frac{100}{(1.06)^{10}} + \frac{100}{(1.06)^{20}} + \ldots\ldots \frac{100}{(1.06)^{90}} = \$226.$$

That is, one would be justified in spending $226, instead of $100, or 126 per cent. more.

To last 40 years, instead of 10 years; interest as before?

$$C = \$100 + \frac{100}{(1.06)^{10}} + \frac{100}{(1.06)^{20}} + \frac{100}{(1.06)^{30}} = \$204.42,$$

or 104 per cent. more.

To last 300 years instead of 60 years, at 6 %?

$$C = \$100 + \frac{100}{(1.06)^{60}} + \frac{100}{(1.06)^{120}} + \ldots\ldots \frac{100}{(1.06)^{240}} = \$103.12$$

or only 3 per cent. more

Note the small allowable increase of cost when the first proposed structure has a long life.

If an iron rail will last 5 years and a steel rail 20 years in the same track, what comparative outlay, with interest at 4 per cent., will be justified?

$$C = \$100 + \frac{100}{(1.04)^{5}} + \frac{100}{(1.04)^{10}} + \frac{100}{(1.04)^{15}} = \$305.27.$$

or the steel, including laying, is worth *three* times as much as the iron, including laying.

But suppose the iron rails, in a road of light travel, will last 15 years, and the steel 60 years, interest as before?

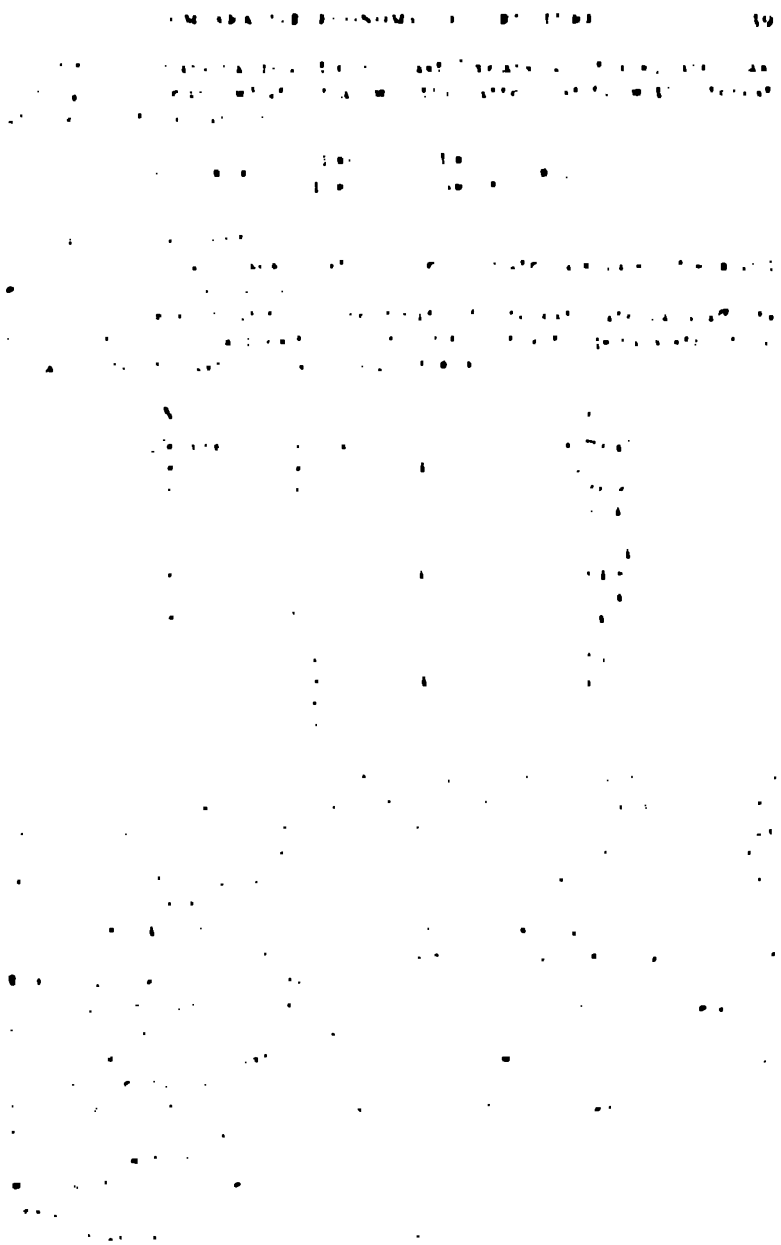
$$C = \$100 + \frac{100}{(1.04)^{15}} + \frac{100}{(1.04)^{30}} + \frac{100}{(1.04)^{45}} = \$208.50.$$

or twice as much.

If an ordinary post and rail fence will last 20 years and a stone wall 100 years, what outlay will the wall justify, when money is worth 5 per cent.?

$$C = \$100 + \frac{100}{(1.05)^{20}} + \ldots\ldots \frac{100}{(1.05)^{80}} = \$159.26$$

or 60 per cent. more.



Let $C$ = cost and assumed value of the structure with longest life.

$N$ = its life in years.

$S$ = probable market value as scrap.

$r$, $r_1$, $r_2$ = equivalent relative values of other structures to be compared with $C$.

$n$, $n_1$, $n_2$, = their respective lives in years.

$s$, $s_1$, $s_2$, = their market value as scrap.

The amount of \$1.00 at compound interest for $n$ years at $r$ per cent. $= (1 + r)^n$, and for $N$ years is $(1 + r)^N$. Log. amount $= N \log. (1 + r)$.

The cost of the structure of longest life, at the end of its life, $= C(1 + r)^N - S$. (1.)

On the other hand, by making use of a succession of structures, with shorter life of $n$ years each, the cost at the end of $n$ years would be $r(1 + r)^n - s$.

At the end of $2n$ years it would be

$$r_1(1 + r)^n - s_1 + [r(1 + r)^n - s](1 + r)^n = r_1(1 + r)^n + r(1 + r)^{2n} - [s_1 + s(+ r)^n]$$

At the end of $N$ years it would be

$$r_2(1 + r)^n + r_1(1 + r)^{2n} \ldots . r(1 + r)^N - [s_2 + s_1(1 + r)^n \ldots . s(1 + r)^{N-1}].$$

By means of the formula for summation in a geometrical progression, if $r = r_1 = r_2$, and $s = s_1 = s_2$, the expression becomes

$$\frac{(1 + r)^N - 1}{(1 + r)^n - 1}[r(1 + r)^n - s]. \quad (2.)$$

Equate (2) with (1), obtaining

$$\frac{(1 + r)^N - 1}{(1 + r)^n - 1}[r(1 + r)^n - s] = C(1 + r)^N - S,$$

from which

$$r = \frac{(1 + r)^n - 1}{(1 + r)^n[(1 + r)^N - 1]}[C(1 + r)^N - S] + \frac{s}{(1 + r)^n}. \quad (3.)$$

*Example 1.* It is proposed to erect a bridge of a certain span for a railroad. A steel riveted bridge will cost \$6,900, and will last 85 years. A wooden bridge will cost \$4,500, and will last ten years; or, if it is covered, at an expense of of \$450, it will last 20 years. Which construction will be most economical, if interest is computed at 6 per cent. per annum?

$$\text{By (3)}^* \quad r = \frac{.791}{1.79} \cdot \frac{141.70}{140.70} \cdot 6900 = \$3{,}065,$$

for the uncovered bridge.

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*Log. 1.06 = .02531. Mult. by 10. 0.2531 = log. 1.791.
Mult. by 85, 2.15135 = log. 141.70

needs in the structure have been modified; therefore fresh calculations with the latest data should guide the proper choice of each structure in the series.

C. The investigation may be taken up in a different way. A certain structure or machine costs $A$ dollars, it requires the expenditure of $R$ dollars for maintenance and repairs at intervals of $n$ years: it will last for $N$ years: and when worn out it may have a scrap value of $S$ dollars. A second structure or machine for accomplishing the same object may be represented as to value by similar letters. Which of these will be the more economical, as a permanent thing, the rate of interest being $r$ per cent., payable annually?

Compute the amount of *present capital* sufficient to provide *permanently* for each of these structures or machines, and the one which requires the smaller capital will be the more economical. Or, find, by the same method, what the cost $A$, of a (perhaps new) appliance must be, to be more economical than a similar appliance in use, under various suppositions as to the life, cost of maintenance, etc.

The present capital required for any structure will be made up of three parts,

1°. $A$, the cost of the machine or structure.

2°. A sum which, put at interest at $r$ per cent., will increase in $n$ years by an amount $R$. This sum will be $\frac{R}{(1+r)^n - 1}$. If $r = 6$ per cent., $1 + r = 1.06$.

3°. A sum which, put at interest at $r$ per cent., will amount in $N$ years to itself plus $(A - S)$. Since, at the end of $N$ years, the worn out structure will be sold for $S$ dollars, there will result a sum sufficient to enable one again to expend $A$ for a new structure, and have the original sum remaining, which in another $N$ years will amount to a sufficient sum to purchase a third structure, and so on indefinitely This sum is $\frac{A - S}{(1+r)^N - 1}$.

The total present capital involved in the use of any structure is therefore

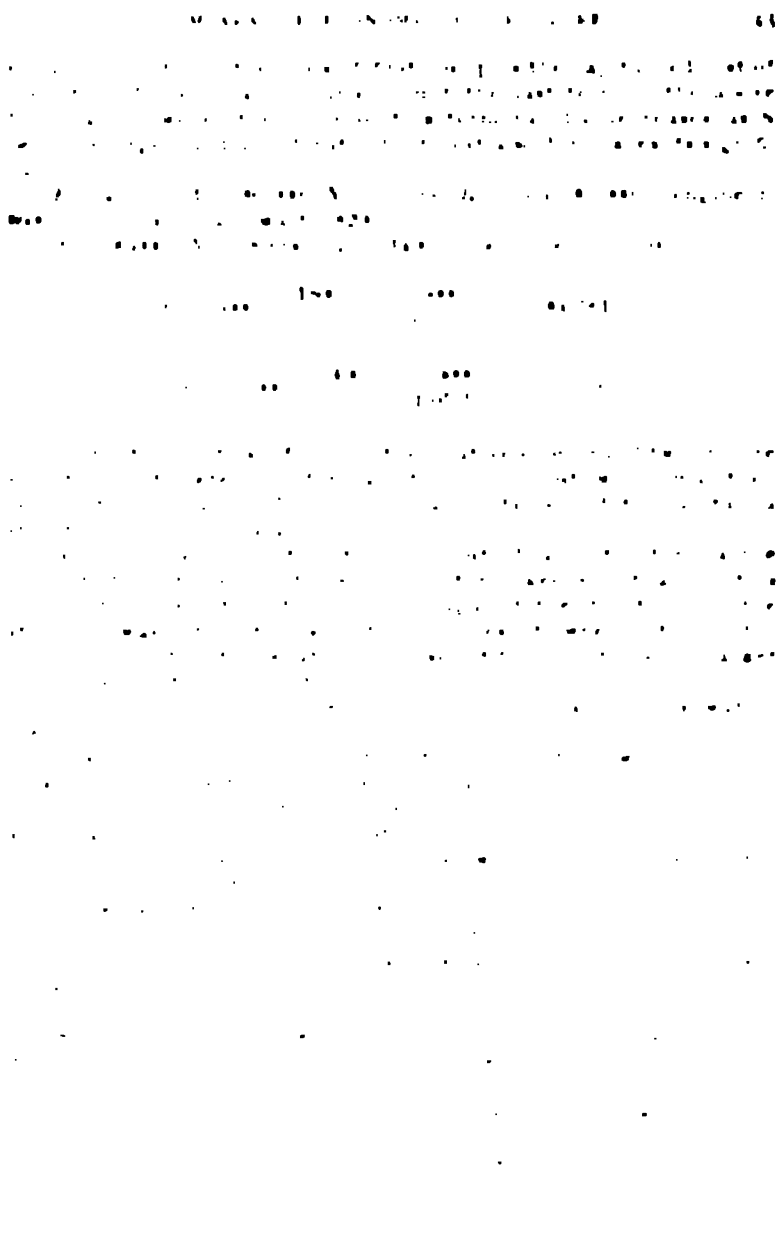
$$C = A + \frac{R}{(1+r)^n - 1} + \frac{A - S}{(1+r)^N - 1}.$$

[If the interest, at rate $r$ per annum, is payable semi-annually, the above denominators become $(1 + \frac{1}{2}r)^{2n} - 1$ and $(1 + \frac{1}{2}r)^{2N} - 1$].

The formula becomes simplified if $S$ is quite small in comparison with the first cost $A$, and if $R$ is the uniform annual cost of main tenance, repairs, coal, attendance, etc., as in the case of a pumping engine, when $n = 1$, and

$$C = A + \frac{R}{r} + \frac{A}{(1+r)^N - 1}.$$

It is seen not to be strictly correct to compare two pumping engines, for instance, as a permanent investment, and assumed of



first cost, $S$ will be the excess, and the total cost of renewal will be $A + S$.

The annual payment to renewal fund will be:

$$(A - S)\frac{r}{(1+r)^n - 1}.$$

The annual interest charge is $Ar$.

The *total annual cost* of the structure will therefore be

$$Ar + R + (A - S)\frac{r}{(1+r)^n - 1}.$$

*Example.*—The relative economy of a wooden and a steel bridge for the same location, 5 spans of 150 feet.

Wooden bridge—first cost $A$ = \$25 per ft., = \$18,750. Scrap value, \$2 per ft., = \$1500. Life, 10 yrs. Annual repairs, watchmen, etc., \$1000. $r$ = .06. Then

$$1{,}125 + 1000 + 17{,}250 \times 0.07587 = \$3{,}434.$$

Steel bridge—first cost = \$60 per ft. = \$45,000. Scrap value = \$7.50 per ft. = \$5,625. Life 60 yrs. Annual repairs, no watchman, \$150. $r$ = .06. Then

$$2{,}700 + 150 + 39{,}375 \times 0.001875 = \$2{,}924.$$

Thus a saving of \$510 per annum is made by using the steel bridge, to say nothing of the greater security from fire.

## EXPERIMENTAL WORK IN NAVAL ARCHITECTURE.

PROF. H. C. SADLER.

The assistance which theory obtains from experiment in any science is unquestionable. This is perhaps more especially the case with applied sciences such as engineering.

Experiments may be conducted in one of two ways. Firstly, the problem in question may be discussed in all its details, and, so far as experience with something of a similar nature can be called in to its assistance, a solution obtained.

The result, if of an engineering nature, may take the form of a structure in which time will decide whether the original surmises were correct or otherwise. Provided the whole stands the tests of time and general working, it may be considered a success in that it has fulfilled the necessary requirements, but by what amount it is on the safe side or how nearly it is a failure, is to a certain extent an indeterminate quantity. Such a process may be called an experiment on a full sized scale.

sel is towed and the force required or the resistance to motion at any speed obtained. The truck is driven by a motor which is capable of variation of speed to any desired extent. Devices for recording time and distance are also fitted, as well as suitable apparatus for testing model propellers and determining the thrust, revolutions, turning moment, etc.

The models of vessels will be from twelve to fourteen feet in length and constructed of paraffin wax or wood.

Great care must be taken in the preparation of these to ensure their being exact reproductions of the form required. A specially designed machine somewhat on the principle of a pantograph is used for this purpose. When finished the form is tested and when correct the model is ballasted to the required immersion, and attached to the dynamometer in the above mentioned truck. This latter is then moved at varying speeds and the pull on the dynamometer, that is the resistance of the vessel to forward motion, registered.

In this way a curve of resistance in terms of speed is obtained for the model in question. By repeating such experiments upon different types of models, the effect of variation of form upon resistance may be readily determined.

In passing from the model to the full-sized vessel recourse is had to Froude's "Law of Comparison," which stated briefly is as follows: two vessels moving at corresponding speeds—that is at speeds varying as the square root of their respective linear dimensions, will have their wave making resistances proportional to the cube of their linear dimensions, the frictional resistance being treated independantly in the usual way. Thus the resistance of a full-sized ship may be determined with a high degree of accuracy from the results of trials upon models of say one-thirtieth to one-fortieth its size.

The other important question upon which systematic experimenting is required, is that of the propeller. At present, although a great amount of valuable work has been done upon this subject by the Froudes and others, there still remain a number of points upon which information is required. In this, as in the case of the model and ship, the laws connecting the results of model propellers with those of full size are of a similar nature.

In a short article, such as this, it is impossible to give a comprehensive account of the various problems that arise in connection with the resistance and propulsion of ships, but it may be mentioned that a full enquiry into the subject involves not only numerous experiments upon models of ships and propellers independently, but also upon the two in conjunction. The presence of the ship as influencing the performance of the propeller, and the action of the propeller as modifying the resistance of the ship, are questions that open a wide field for investigation.

Other problems such as those relating to rolling and pitching of vessels and the influence of bilge keels upon these qualities and

THEORETICAL EFFICIENCY OF VARIOUS EXPANSION
CURVES FOR STEAM

For the purpose of making a more careful comparison, the writer has calculated the theoretical efficiencies for both isothermal and adiabatic expansions of (1) superheated steam, (2) dry saturated steam, and (3) steam containing 24 per cent. moisture, the initial steam pressure, the ratio of expansion and the back pressure being the same in all cases. For superheated steam Zeuner's equation, as given in English units by Peabody in his Thermodynamics, p. 130, has been used, viz.:

$$p\,v = 93.5\,\tau - 971\,\rho^{\frac{1}{2}}.$$

The value of $\gamma$ for superheated steam has been taken as 1.33 (*see Peabody's Thermodynamics*, p. 129). The work done during adiabatic expansion was calculated by the well-known formula,

$$\int p\,dv = \frac{1}{\gamma - 1}\,p_1 v_1\left[1 - \frac{1}{r^{\gamma-1}}\right].$$

For saturated and moist steam the value of $\gamma$ was obtained by Zeuner's equation (*see Wood's Thermodynamics*, p. 152). In the case of saturated steam the work done during adiabatic expansion was calculated according to the theoretical law as well, and the value thus obtained is the one given (see Wood's Thermodynamics, p. 177).

To obtain the work done during the isothermal expansion of the superheated steam the expansion curve was plotted upon cross section paper from Zeuner's equation, making $\tau$ constant. The adiabatic curve for superheated steam was also plotted and the area included between the two curves and the release line was measured by a planimeter. Multiplying by the proper constant and adding to the work of adiabatic expansion we obtain the work of isothermal expansion.

The degree of superheating was so chosen that at the end of the adiabatic expansion the steam would be dry saturated steam. The amount of heat delivered to the steam up to the point of cut off above the assumed feed water temperature was found from the steam tables and the specific heat of superheated steam, which was taken as 0.4805. Peabody's Steam Tables were used.

The amount of heat transmitted to the steam during isothermal expansion is equal to the excess of external work done plus the excess of internal energy at the end of the expansion over the corresponding quantities for adiabatic expansion. The excess of external work done was found graphically as described. The excess of internal energy, since the steam is dry saturated steam at the end of the adiabatic expansion, is equal to the heat required to superheat the steam at constant volume from the temperature at the end of the adiabatic expansion up to that at the end of the isothermal expansion.

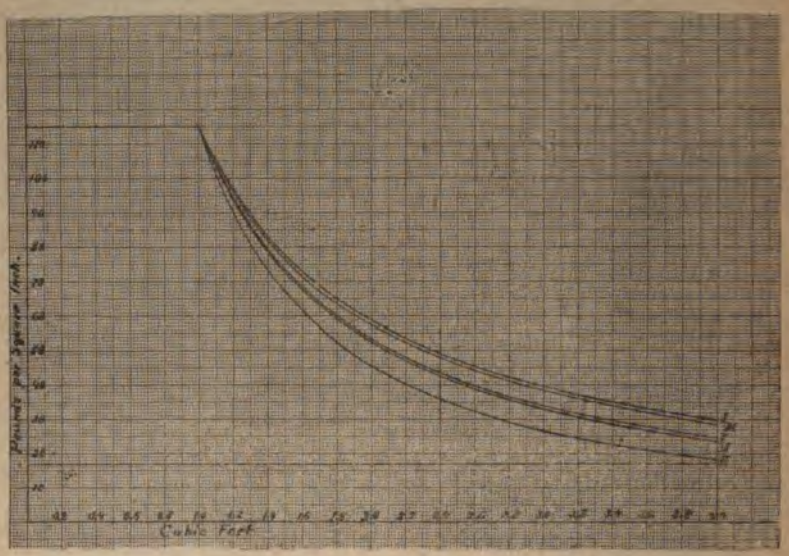
In the cases of saturated and moist steam the equilateral hyperbola was used in place of the true isothermal. As in the case of

superheated steam the heat absorbed during expansion is equal to the sum of the excess of external work above that of adiabatic expansion plus the excess of internal energy at the end of the expansion. The excess of external work was found by calculation and [illegible]. The internal energy at the end of the expansion [illegible] the heat of the liquid plus the internal work of vaporization plus the specific heat at constant volume times the degrees of superheat. If the steam is moist it is equal to the heat of the liquid plus the internal work of vaporization times the quality of the steam.

The following table gives the results of the calculations. [illegible] of heat and work [illegible] per pound of steam at [illegible]

That is, the steam is in all cases assumed to be used in a cylinder, having a stroke displacement of four cubic feet and no clearance. In the case of the moist steam it is assumed that the steam is delivered to the engine in that condition, and not that the moisture is due to cylinder condensation.

Comparing the efficiencies of the same kind of steam when expanded adiabatically and when heat is absorbed during expansion, it appears that for superheated steam isothermal expansion is more efficient than adiabatic expansion, but that for saturated and also for moist steam the reverse is true. The case most commonly met with in practice is that of moist steam containing from 20 to 40 per




STEAM EXPANSION CURVES.

cent. of moisture at cut-off. In this case the absorption of heat from a steam jacket during expansion is a positive detriment. Of course the effect of the steam jacket in reducing cylinder condensation is the main argument for its use, but it may be well to consider that the action for the jacket during expansion and during exhaust tends to reduce the economy of the engine, so that the next result may not in all cases be upon the right side of the balance sheet. May it not be wise to inquire if some other method of preventing cylinder condensation should not be adopted which shall avoid the wastes incident to the use of the steam jacket? The use of superheated steam is evidently an advantage, either with or without a steam

## SHRINKAGE OF SOIL ROLLED IN SIX INCH LAYERS

between slope stakes, with side slopes of approximately 1 to 1, having been partially filled under a previous contract.

The soil was excavated from an area of 64 acres to an average depth of 0.78 ft. About 59 acres of this area contained stumps. The land from which the soil was excavated was called sprout land,—land which had been cleared of forest growth and again allowed to grow over with trees and brush.

The volume of the soil measured in excavation was 80355 cubic yards.

The volume of the soil after it was deposited and compacted in the cut-off trench was 50735 cubic yards, or 29620 cubic yards less than the volume measured in excavation. The final levels were taken a few days after the completion of the work.

From the above it follows that the shrinkage of the soil was 37 per cent., calling the volume of 80355 cubic yards 100 per cent. This shrinkage includes roots one-half an inch or more in diameter and stumps so far as they were originally embedded in the soil, but which were removed and burnt. Roots one-half an inch or more in diameter, stumps or other wood were not allowed to be deposited with the soil in the cut-off trench. The soil was free from stones.

The volume of the soil excavated was determined from levels taken when there was no frost in the ground. The first levels were taken after the ground was cleared of trees and brush, which were removed and burnt or otherwise disposed of, and before the contractor had commenced grubbing; and the final levels after the final excavation was finished. The volume of the soil excavation includes the roots and stumps so far as the same were imbedded in the layer of soil excavated. The levels extended over the entire area stripped and were taken not more than 25 feet apart: that is, not less than 70 cuts or depths of soil were determined for each acre. The ground was divided into squares 500 ft. on a side, the corners of which were permanently marked, and the sides were used as base lines for the cross section work. The average depth given, 0.78 ft. is the total volume of the soil excavated divided by the area, and is only intended to give some idea of the depth of the soil stripping. All the soil containing 4 per cent. or more of organic matter is removed from the reservoir site.

The volume of the soil when in the trench was calculated from accurate cross sections, taken not more than 25 feet apart before and after the filling of the trench.

Before rolling the soil it was watered as much as it would bear without sticking to the roller.

The type of roller which was used weighs about 6000 pounds, and is drawn by two horses. The cylinder of the roller is 5 feet long and is composed of 19 cast iron wheels, 3 inches thick at rim, 10 being 2 feet 11 inches, and 9, 2 feet 8 inches in diameter, respectively, arranged alternately.

# WATER SUPPLY OF LARGE CITIES

proceeding for most towns to start any action against their neighbors.

The rapid growth of American cities, with the consquent increase in the pollution of streams, has been such that the future prosperity of many large places depends upon better and more wholesome supplies of water being furnished for domestic purposes.

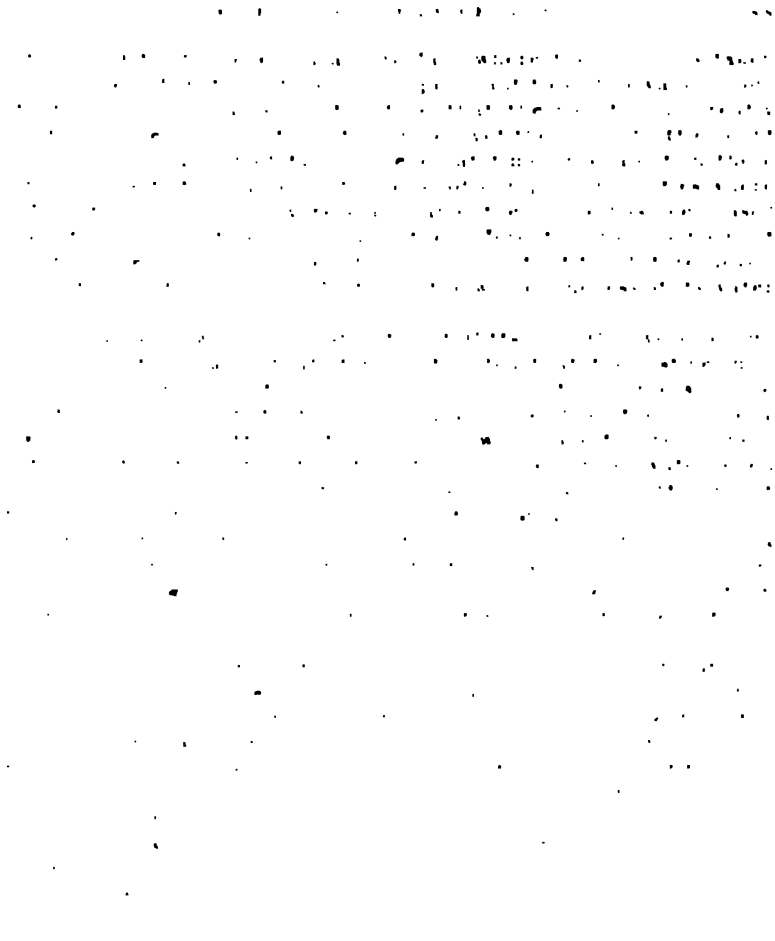
At Chicago where the water supply is taken from Lake Michigan, the sewage pollution became such that the city was obliged to expend over $32,000,000 to dilute the sewage with water from the lake and turn the flow down the Illinois and Mississippi valleys,—a proceeding which has relieved the difficulty at Chicago, and caused serious complaints from the cities along the river through which the sewage is discharged.

The City of St. Louis which at present secures its water from the Mississippi River, has started legal proceedings in the U. S. Courts to compel Chicago to discontinue the pollution of the Illinois and Mississippi Rivers. Yet at St. Louis the entire sewage of the city is discharged into the river. A commission of hydraulic engineers has recently made an investgation and report relative to the best method of furnishing St. Louis with a pure and wholesome supply of water in the future, and has recommended abandoning the present source of supply, and obtaining water from the watershed of the Meramec River, where a first-class water for both domestic and manufacturing purposes can be had at an elevation which will give the necessary pressure in the distribution mains, with a gravity flow from the storage reservoir. The advisability of the change is very apparent from the fact that the present water rates for the dirty river water will be more than sufficient to pay all expense, interest on cost of construction, and sinking fund for the redemption of bonds.

If the present source of supply is continued in the future, filtration will be absolutely necessary, which will require an expensive plant, and the use of an average of 500 lbs. of sulphate of alumina per million gallons. The sulphate of alumina is decomposed in the chemical action which takes place in this process, the sulphuric acid uniting with the bases of the carbonates of lime and magnesia in the water, forming sulphates which are the elements of permanent hardness in water, and constitute the incrustating ingredients which form hard scale in boilers and render a water poor for steam purposes.

The influence of the filter interests is becoming very great, and there are good reasons to believe that in certain instances it has been exerted to such an extent that the installation of filters has been recommended where other methods of supply would have been better and more economical for the consumers.

There are places however, where filtration of the water supply is the only posible safe-guard against those diseases which result from the use of polluted water, as for instance, is the case at such lake



at times of greatest turbidity of the Potomac river water was recommended by the engineer commission and adopted by Congress.

At Louisville and Cincinnati exhaustive experiments were made with various forms of mechanical filters, and plans adopted for the filtration of the Ohio river water.

At Cincinnati, however, a first-class gravity supply was available from a watershed in the Cumberland mountains, in eastern Kentucky, which was reported adversely, for the reason that the estimated cost ($27,000,000) was very large compared with the quantity of water needed for the city supply.

During 1900 and 1901 extensive experiments were made at New Orleans to determine the advisability of filtering the Mississippi River water for the supply of that city, with the result that the investigators reported that satisfactory results could be obtained by sedimentation in settling basins, coagulation, and filtration with rapid or mechanical filters. The results at New Orleans are to a certain extent applicable to the water at St. Louis, but since at times the amount of sediment which would remain in the St. Louis water after 24 hours sedimentation, would be greater than the average amount carried by the river at New Orleans, it is still on open question whether a perfectly pure and wholesome supply can be obtained by filtration of river water at St. Louis at reasonable cost, and since water of much better quality for both domestic and steam purposes can be obtained at less expense to the consumers by gravity flow from the upper watershed of the Meramec River, it is quite probable that the latter project may be adopted.

The large amount of experimental work which has been done to determine the efficiency of various kinds of filters with the different waters to be treated, has been of immense benefit to the science of water purification, but by no means establishes the claim that equally as good results may be obtained in the large plants necessary for the supply of cities as in the small apparatus for experimental purposes. Where water carries a large amount of fine sediment, the time required for sedimentation is a function of the depth of the settling basins and of the movements of the water through the basins. In small experimental tanks the water is brought to a state of rest quickly, and as the depth through which the fine particles have to fall is small the time determination for sedimentation has but little bearing on what may be needed in actual practice.

Where coagulation is necessary, a complete admixture of the chemicals and water is easily obtained in small plants, while in the treatment of large quantities this is not always obtained.

The quantity of water which must be provided for depends upon the probable future growth of the city, and the average number of gallons which may be required daily for each inhabitant, both of which are largely conjectural.

From investigations of the amount of water used for different

Storage reservoirs are very beneficial for improving the quality of all surface waters so collected, especially if the reservoir sites have been properly cleared of all vegetable matter.

Filtered water when stored must be protected from the light in covered reservoirs or the growth of algae in the water will be such as to render it offensive.

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## THE LAKE SUPERIOR IRON ORE MINES.

L. DOUGLASS ANDERSON, '01.

The iron ore fields of the Lake Superior region are so extensive in area and so rich in deposits as to have become a factor of the greatest importance in the iron making industry of the world. For this reason their description bears not the restricted interest attached to a matter of local importance, but rather that concerned with an industry of international significance.

The principal iron ore districts, or "ranges" as they are commonly called, are five in number, named as follows, in order of discovery:

The Marquette, in the State of Michigan.

The Menominee, mainly in Michigan and somewhat in Wisconsin.

The Gogebic, of the same description.

The Vermillion, in Minnesota.

The Mesaba, in Minnesota.

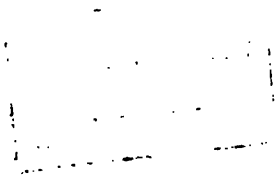
To these might be added the Michipicoten district of the province of Ontario, Canada, near Sault de Sainte Marie, as last year its single mine, the Helen, produced 230,000 tons of ore.

For a long time the upper Peninsula of Michigan, literally a "howling wilderness" in the first half of the 19th century, was invested with rumors of marvelous mineral wealth, gold, silver and copper being reputed to be exceedingly abundant. Despite these rumors the State of Michigan, as the lower peninsular considered itself, regarded the upper peninsular as an unwelcome bantling left upon its doorstep in return for the land comprising the county of Lucas which was taken from the then territory and attached to Ohio. At that time, Wiconsin, also a territory, and to whom the upper peninsula once belonged, was too busy buying furs and keeping watch on the Indians, to notice the loss of a trifle like eighteen thousand acres of land.

Although the first explorers sought the precious minerals it is claimed that iron ore was also known to the trappers of the Hudson Bay Fur Company as far back as 1830. Yet the first authentic discovery of iron ore must be considered as one of the great results of the work of Dr. Douglass Houghton, who labored so hard for the

OLD HARD ORE MINE.

LAKE SUPERIOR IRON MINING CO., NEGAUNEE, MICH.



The first notice of the Gogebic range occurs in the report of Dr. Randall, assistant to Dr. D. D. Owens, in charge of the geological survey of Wisconsin. The discovery of ore in 1848 was fully described in Dr. Owen's report of 1852, stating the ore to be in the form of a stratified belt about 300 yards wide, dipping to the northwest, with its outcrop appearing along the summit of a mountain range.

Captain N. D. Moore shipped ore to Milwaukee from large deposits of soft brown hematite found by him in 1880. In 1883 explorers from the old ranges worked their way over to the Indian reservation near Ashland, Wisconsin. Their prospecting south of the present city of Bessemer laid bare the situation of the since far-famed Colby mine. Not long after the discovery of this mine an "option" for a lease was taken out by Mr. A. Laufear Norrie, of New York City, upon land which his men opened up and proved to be one of the most wonderful underground producers that the country has ever known. The first regular shipments from this range began in 1884 with one cargo of 1022 tons from the Colby mine, followed by 119,860 long tons in 1885 from eight producing mines, the next season witnessed a leap to 747,589 tons from twenty-one mines.

As on the Marquette and Gogebic ranges, the first ore deposits on the Vermillion were announced by the state geologist, Mr. H. H. Eames, who made note of its presence in 1866. In 1875 explorers under direction of Mr. Stuntz, of Duluth, found a seam of ore thirteen feet wide of hematite so hard that it was almost impossible to break it with the tools then available. This seam, which had been cut by touching across the ore formation, ultimately proved to be that operated by the Minnesota Iron Company. Five years later systematic exploration was taken up. The range had no great development however until the Duluth and Iron Range railroad was built in 1884. This road passed into the control of the Minnesota Iron Company two years later, under whose superintendent, Mr. D. H. Bacon, now of the Tennessee Coal, Iron and Railroad Company, additional discoveries were made and the mines rapily developed.

On the Mesaba, the newest and at the same time the most remarkable of the ranges, ore was noticed as early as 1850. Yet the earliest explorers were for several years greatly disappointed, many uniting in condeming the district entirely, owing to the fact that all ore found was lean or blended with jasper. Another disturbing peculiarity of the field was the fact that the deposits were very flat, while the lenses of the old ranges stood at a very high angle to the horizon. Soft hematite was found in 1890 on the site of the Mountain Iron mine. Shortly afterwards the Biwabik, Cincinnati, Hale and others were opened. At the Biwabik the much famed steam shovel operations of this range were inaugurated. The panic of 1893 coming on at this time stopped all development on the range, not, however, before it had been proved that the ore here could be handled easily with steam shovels.

[illegible] table giving the production in tons from each [illegible] year as well as for three previous years at the [illegible]

| [illegible] | 1894 | 1895 | 1896 | 1897 | [illegible] |
|---|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
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| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
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[illegible]

Huronian rocks to which they have been carried. The Menominee range is the only one where any fossiliferous remains have been found, these being very rare. One result of this limestone formation is the exceedingly wet nature of the majority of mines opened here. All limestone regions have been noted for underground caverns and passages of great length. The only relieving feature of these limestone beds is that they lie at a sharp angle to the horizon. If they were flat as in the Joplin zinc district of Missouri the flow of water would be prohibitive, even now being a heavy item of expense.

The first ore discovered was in the nature of an outcropping on the surface, leading the discoverers to believe that they had no real mining to do and that their only labor would be to break the ore and load it into cars. As a result the first mining operations were carried on in huge open pits, with the aid of derricks, much after the manner of quarrying building stones. These large pits on the Marquette range in particular are today one of the sights shown to visitors. As an instance of the ignorance of the true nature of the ore formation may be cited the famous litigation for the possession of Jasper Knob in Ishpening, which was believed to be a veritable mountain of iron. After several thousands of dollars had been spent the legal owners began work upon their supposed bonanza. A bitter and costly experience was in truth theirs, for this "Knob," or hill, proved to be a great mass of jasper covered with a very thin skin of iron ore, which even today draws the attention of visitors by its dark blue colors sparking in the sunlight.

With the passing of time, however, came a better understanding of the nature of the problems to be dealt with, so that now the winning of the ore is attacked in a truly scientific manner. The methods used in many places are largely patterned after those of England, the Cornish miners being very prominent in the working of the Lake Superior mines. All the methods in use may be divided into four distinct systems, viz, overhead stoping, caving, milling and steam shovelling.

In "overhead stoping," after the situation of the ore deposit has been proven by the diamond drill, the usual plan is to sink a slanting shaft in footrock, following the dip. Ordinarily the shaft is of oblong section, partitioned into two hoisting ways and a third way containing the ladder and piping to the pumps and air drills. When the shaft has reached a depth of about 65 feet a drift (as the galleries or headings are usually termed) is driven horizontally across the deposit. About the center of the deposit another drift is driven longitudinally along the deposit for about twenty-four feet. Ore is then broken out sideways and upwards, across the lense, falling to the original level, and then being conveyed to the shaft. In this manner a "room" about 24 feet wide, extending to the soil or rock capping above and equal in length to the width of the deposit, is cut out, the workings being followed by timber scaffolding throughout, except in such rare

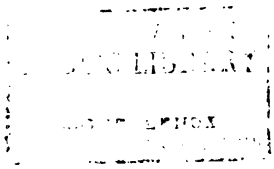
worked out, the rock capping being supported by timber. When these timbers show signs of distress, or if still standing when the seven-foot slice has been cut across the ore body, they are blasted away and the surface allowed to fall in to that extent, the floor being previously covered with rough timbers to form a good roof for the next slice. Not infrequently the ground is permitted to cave before the slice has been completed, the worked out cavities coming in almost as soon as excavated, so that sometimes miners may still be working on the same slice which has caved within thirty or forty feet of them. The timbered rises are divided into two compartments, a ladder way and an ore chute, or "mill," as it is locally termed, "milling the ore down" being to run it through the chute. From the mill it falls into cars on the level below and is transported to the shaft and hoisted to the surface. By successive stages all the ore above the level driven from the shaft is thus worked out and the ground permitted to cave in after each slice. In the meantime the shaft has been sunk a further 100 feet and the "second level" started with its various rises and prepared for working as above. The first level is then abandoned and mining continued on the second. As the ore is worked out an immense pit is formed by the gradual caving of the surface, plainly showing the great quantity of ore taken.

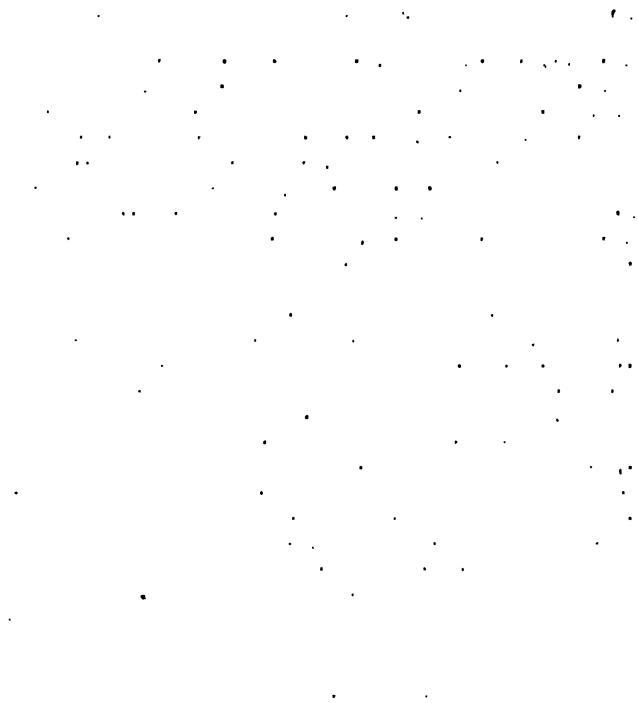
The advantages of caving over overhead stoping are many, the two chief ones being the lesser amount of timber required and the greater safety of the plans. The timber is light, of a temporary character, just sufficient to hold the ground until the miners can withdraw to a new working, whereas in the stoping method it is necessary to use large quantities of massive framed timbers. At first sight caving seems the more dangerous, although in reality it is the safer, despite the fact that it took many years of practice to convince the stubbornly prejudiced miners of this fact. When the ore caves in the caving system it falls only seven feet, as compared with many times this in the stoping system. As a result the falls of ore are confined to small areas and do not occur with resounding crash and attendant catastrophe as would be the case if a large room should give way and collapse. The miners work on solid foot ground and not upon scaffoldings of timber many sets high, which need constant and vigilant inspection to insure them against weakness due to rotting. If nothing else, this matter of the heavy timber renewals in the old mines would cause the choice of the caving system in future work, for the once abundant forests around the mines are no longer standing and timber is quite expensive.

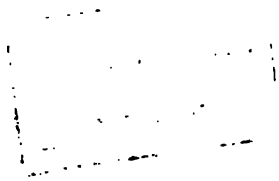
The milling system is not used to a large extent, being principally employed where the overburden of rock and soil is very light and the ore yet so situated that it must be hoisted some distance. The plan is much like the caving system except that the major part of the work is carried on in the open air. Proceeding as previously mentioned, shafts are sunk and drifts driven in the ore body. The

LAKE ANGELINE, ISHPEMING, MICH.

VIEW FROM EASTERN END LOOKING SOUTHWEST.







almost constant service, a train of loaded cars always standing at the shaft mouth on the working level. In fact, hoisting has become so rapid that it has necessitated the installation of electric trams on the surface also to take care of the enormous daily tonnage. At the new "B" shaft of the Norrie mine, the equipment is so planned that they can raise over half a million tons per year through the one shaft.

The Chapin mine and others on the Menominee range use wire rope haulage. The Aragon mine at Norway on the same range uses compressed air, the only one in the entire district to do so. A special compressor on the surface sends the air into the mine at a pressure of 800 pounds per square inch. The locomotives carry large steel tanks in which the air is stored, about a minute and a quarter being required to charge for a trip of one-half mile. By means of reducing valves the air is delivered to the engines at a pressure under 125 pounds. At present five or six cars are hauled at a time. The system works very satisfactorily and has solved one of the many problems of the Aragon. The ore formation here is very long and narrow except in the middle where it widens out. A shaft in the ore body, sunk at great expense, was lost by the coming together of the ore pillars. The present hoisting shaft, 700 feet distant from the main ore body, is sunk in solid jasper and therefore quite permanent. The long trams involved, for a time threatened to overcome all advantages of a permanent shaft. The installation of the compressed air haulage system completely met the exigency.

On the Marquette range the richest mines are on the edge of Lake Angeline, three companies, the Lake Superior, the Cleveland-Cliffs and the Pittsburg and Lake Angeline, owning the adjoining land and the lake basin. The main ore deposits were under the lake and for several years miners worked underneath the waters. The presence of this lake was a constant menace and a source of much anxiety to the mine managements. Finally it was deemed advisable to pump out this lake, huge though the job appeared to be. For it must be borne in mind that this lake covered an area of 103 acres, being nearly 50 feet deep in the middle, and was estimated to have contained over a billion gallons of water. The outlet was lowered about six feet, as much as the topography of the country would allow. A large scow was built and moored near the center of the lake, a launder being built out on piles to it. On this scow were placed the boilers and centrifugal pumps. The work required six months for its completion. The end of this time found an unexpected trouble remaining in the presence of mud, from six to twenty feet in depth, too thick to pump and to thin to shovel. It has been the cause of several bad scares, notably when at times in the caving system employed at the Cleveland Lake Shaft the rock capping broke through and the mud forced itself into the mine, running with considerable freedom, and compelling the miners to wade through it waist deep. There is no danger to the men as it runs slowly, but

# IMPROVEMENTS MADE IN HEATING AND VENTILATING PLANTS IN THE PUBLIC SCHOOLS OF DETROIT SINCE 1898.

RALPH COLLAMORE, '97.

The object of this article is to give some idea of the improvements made in the arrangement of the apparatus in the "forced blast" system of heating and ventilating as installed in the public schools of Detroit during the past few years. While these improvements have not changed the original scheme of the system, they have done much to simplify both the handling and the arrangement of the apparatus. The effect of these improvements has been to make the recent plants equal to the best of their kind anywhere in the United States. These results have not been attained at a single bound but are the result of close observation and a desire to improve wherever possible.

Not long ago an architect from the State of Washington came to Detroit while on a tour of inspection. He had examined the heating and ventilating plants in the schools of St. Louis, Chicago, New York and several other cities, but after inspecting the plant in the Gillies School of this city, he said that it was the best he had seen. He was sent east by the Board of Education of his home city to get the best ideas concerning the arrangement of school buildings and the methods used to heat and ventilate them, and he said that he would recommend for adoption as a heating system the arrangement he found in the above named school. Such comments as these have led the engineers for the Board of Education of Detroit to feel that they are right in assuming that the plants have kept pace with the times.

A brief description of the "forced blast" system as it existed in the schools in 1897 had best be given here.

The plant itself consisted of a boiler, engine, steel plate fan, pump and receiver, tempering coils, main heating coils, traps for returns, galvanized iron ducts for carrying the air from the fan to the vertical flues leading to the rooms, and several other smaller pieces of apparatus. The fresh air was usually admitted through basement windows or special openings near the ground level, drawn through the tempering coils to the fan and delivered by the fan through the heating coils into the main distributing duct, and from the main distributing duct to the vertical flues leading to the various rooms where the air was delivered about seven feet from the floor. Vent openings placed immediately under the fresh air openings in

change made the plant more compact and eliminated one item of repair, namely, the belt, at the same time lessening the chance of communicating sound to the rooms.

(4) A definite practice was determined upon regarding the proportioning of heating surface in the heating and tempering coils and also on velocities of air to be used. It was determined to place five-eighths of the total heating surface in the heating coils and three-eighths in the tempering coils, and this division has been very satisfactory. There has also been a tendency to reduce the velocity of the air and at present the following velocities are used: Fresh air duct, 800 f. p. m.: through tempering and heating coils, 1200 to 1500 f. p. m.: in ducts, 750 f. p. m.: in flues, 400 f. p. m.: and through heat and vent openings, 300 f. p. m. The general effect of reducing velocities has been to make the plants easier to handle and more responsive to adjustments.

(5) The next step was to place the heating and tempering coils and direct radiation all on one system and bring the returns back to the receiver without the use of traps. The exhaust line was connected into this low pressure line and any deficiency of steam was supplied through a reducing pressure valve. The receiver was provided with an overflow pipe which had a water seal. This seal was frequently blown out so the overflow pipe was abandoned and an equalizing pipe between the receiver and the low pressure line was substituted in its place. This last arrangement has proved very satisfactory.

About this same time the coils which were placed in the vent flues to the toilet rooms to insure a positive flow of air and which had up to this time been fed from the low pressure system, were connected to an independent system operating at boiler pressure and returning direct to the boiler, so that whenever there is any pressure on the boiler these coils will operate whether the plant is in operation or not.

(6) The next step was a very important one and consisted in changing the method of introducing the fresh air into the buildings. As mentioned before, up to this time the fresh air had been introduced at or near the ground level. It was now changed so that the air entered the system under the eaves of the building and was taken down a special flue to the tempering coils in the basement. In the attic a damper was placed in this flue which was arranged to admit the air either from the outside or from the attic. This has made it possible to re-circulate the air before the opening of school, and thereby save considerable coal and time in warming the rooms. After school commences the damper is set to allow the air to come in from the outside. This damper is operated from the basement and is easily controlled. These advantages are those viewed from an engineering standpoint, but it can readily be seen that it has improved the sanitary conditions.

(7) Automatic stokers and automatic heat regulating appara-

been used wherever possible to drive the fans. This has increased the first cost of the plant, but lessened the operating expenses. The steam piping with this arrangement is very simple since it is possible to have only one low pressure system operating at boiler pressure to feed both indirect and direct radiation. When this system is used an exhaust fan, electrically driven, is used to take the air out of the toilet rooms, thus assuring positive ventilation of these rooms. This air is exhausted directly to the atmosphere so that the balance of the system is not contaminated. Another advantage of this type of plant is the fact that in mild weather the fans can be operated without getting up steam, thus affecting a considerable saving in fuel.

The Eastern High School, erected in 1900, has its own electric plant. This building is divided into three wings and has a separate fan for each wing, all fans being driven by motors. The toilet rooms and chemical laboratory each have an exhaust fan system for removing the air. Besides the five motors there are about 1400 electric lights in the building. The advantages of this arrangement are numerous, long lines of steam piping are avoided, any wing may be heated independently, and the whole plant can be controlled from the engine room. When this building is furnished with throw over service to the Public Lighting Commission's mains it will be as complete an equipment as could be desired.

(9) Recently numerous complaints have been made that oil has found its way into the boilers. Whether this has been due to poor separation in the oil separator on the exhaust line from the engine, or to a poor grade of cylinder oil has not yet been definitely determined. in any case it is probably impossible to eliminate all the oil from the exhaust steam even with the best of apparatus. However, in order to avoid the possibility of any further trouble from this source, the exhaust line has been connected into one or more sections of the heating coils instead of into the low pressure line and the returns from these coils are trapped into the sewer. This avoids any possibility of oil getting into the boiler but at the same time slightly increases the cost of operation.

(10) From some of the schools complaints have been made that the air returning along the floors to the vent flues caused a draught and gave the pupils cold feet. This was especially true where there was but one vent outlet in the room situated immediately under the heat opening. Whenever possible several vent opening are provided, usually by taking off about six inches from the bottoms of the doors leading to the cloak rooms, the vent flue proper leading from these rooms. But in order to overcome this objection completely it is purposed to run one or two rows of steam pipe under the windows in order to take the chill off of the air as it starts to return to the vent openings. It would seem that this would accomplish the purpose but that can be better determined after the experiment has been tried.

(11) In the general improvement the boilers have not escaped

system is decidedly better than that furnished by the furnace gravity system. Carbon dioxide itself is probably not the dangerous part of respired air but it is believed to be an index of the amount of impurity in the air. Mr. Raymond found the best results in the Eastern High and Gillies schools, two of the most recent schools, in which only five parts of carbon dioxide in 10,000 were found.

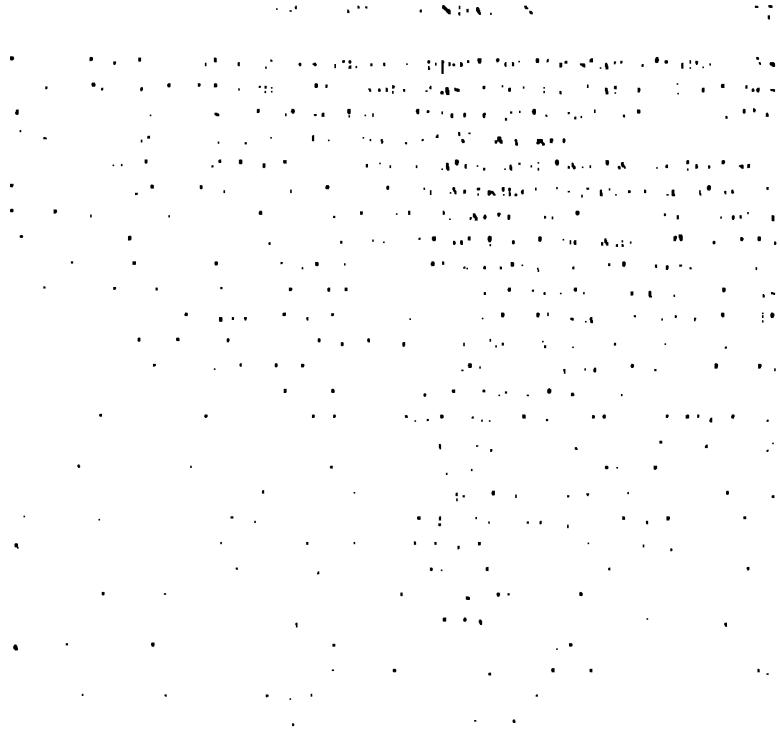
The writer has probably presumed somewhat on the knowledge of the readers concerning the matters touched upon, but to go further into details would probably be tiresome. It would seem that the development of the heating systems has been slow, but this is usually the case where permanent progress is made. Attention to details, earnest thought and careful planning have been the main factors in bringing the plants to their present degree of perfection.

## STEAM STAMP FOUNDATIONS AT THE ISLE ROYALE COPPER COMPANY'S STAMP MILL.

A. L. BURGAN, '95-'96, SUPT. TAMARACK AND OSCEOLA STAMP MILLS.

The location of the Isle Royale Stamp Mill was ideal in all respects save one. The formation there is dry sand with occasional layers of gravel to a depth of 75 feet, where there is a sandstone bed. The serious problem was to build foundations that would withstand the jar caused by stamps with striking parts weighing three tons, striking at a velocity of twenty feet per second and one hundred blows per minute.

With two exceptions the mills in this section have locations where there is a sandstone formation within a few feet of the surface, making it a comparatively easy matter to place foundations equal to the requirements. These are made about fourteen feet deep and twenty feet square, with concrete and timber. In the case of one of the exceptions noted, this concrete and timber was started on sand, and was far from a success. In the other case piles were first driven in the sand, about thirty inches between centers, and the bed of concrete and timber placed on these. I understand this is not considered an entire success. The problem for the management of the Isle Royale Copper Company was then to devise some method which would of a certainty be successful. The method adopted was that of sinking for each stamp a steel tube twelve feet in diameter to the sandstone seventy-five feet below, the tubes to end about fifteen feet below the foundation level and to be filled with concrete. From the top of the tube the foundation was carried up twenty feet square with concrete, and capped with three courses of oak timbers, crossed. The base of the anvil blocks would be entirely over the tubes, while the enlarged



OUR NEW NAVY AN[illegible] ELECTRICAL EQUIPMENT

as we compared the pick of those foreign fleets with those of our own, it seemed to me, and it must have seemed so to every loyal American, that the American fleet, like the nation it represents, outclassed in quality anything that Europe or Asia had in those waters. The American battleship is the finest production of American genius and shipbuilders' art.

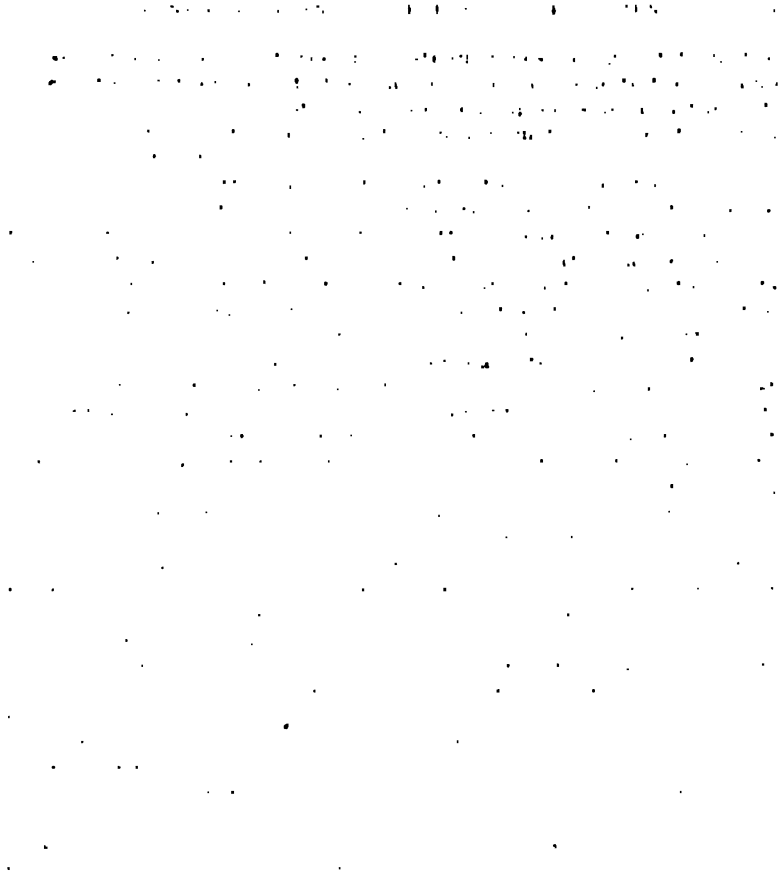
By virtue of the numerous applications and ingenious contrivances, that ponderous, invincible and irresistible mass of steel is made wonderfully susceptible to the touch of the human hand. She defies every caprice of the elements in order to obey her master's will. She is the very embodiment of the genius, the power and the will of the people.

One of the great moral lessons that I have learned during my last cruise, and which has left a lasting impression upon me, is *the significance of a determination in purpose.*

An order would come from the Department for such and such a vessel to proceed at once for such and such a place, a command that must be obeyed at all costs. The wind may be blowing a gale, the seas mountain high, it matters not. She must go. A button from the bridge is pressed, a dial swings in the engine room below, indicating "half speed ahead." The valves are opened, the throttle given a turn or so, the passive crank begins to stir, the monster shaft, to which the propellers are fixed, begins to turn, and in a short while, steadily and noiselessly, the great vessel has swung out of the harbor and has faced the stormy sea and the dashing waves. When all danger is cleared, at the signal of "full speed ahead" she leaps madly upon the waves with a still greater force and determination. She may be ascending or descending, pitching or rolling, but still onward she goes. At times the mighty head seas and the gale combined may come upon her with such a force, that in spite of all her engines can do, her progress is imperceptible or she may even be loosing ground for a time instead of gaining. No matter what obstacles come in her way, leaving out rocks and shoals, as long as her engines are moving and the propellers revolving, she will be advancing, though ever so slowly, till finally one day she comes into a new haven of a new land. Her great task is now over, the elements are conquered, and the purpose is won through steady application of an even pressure of steam and by making every pound of it do its utmost to keep that great shaft turning.

The efficiency of the modern man-of-war has increased wonderfully with the advent of electricity. We can no more compare the modern, electrically equipped man-of-war with those of Nelson's, Paul Jones', or Decatur's vessels, than we can compare our American cup defenders with the Filipino dug-outs.

The use of the electric motor has supplanted a vast amount of
r bor, and has reduced to a minimum the number of heat
d leaky steam pipes throughout the vessel. On our latest



battle circuit is cut in and all other circuits are cut out. The entire ship is in darkness, except the engine room and the dynamo room where the battle covers must be screwed to the air ports, so as to completely bar the light from being seen from the outside. The portable battle lanterns are lodged it a metallic cylinder with a shutter, so they could conceal the light completely or just show enough to set a fuse or a shell or attend to some other little detail without attracting attention at a distance. In such cases, a lead colored vessel is like a phantom on the high seas. It is next to impossible to detect her until she is almost upon her prey and then it is too late.

The general alarm bells are worked by springs, which are so arranged that three general alarms can be given on one winding. The pressing of one button sets off every bell in the ship at the same time, as the circuit is completed by the pressing of the button and the electromagnets pull up the ratchets and release the wheels which keep the bells ringing until they have made one complete turn, and then the ratchet falls back in the slot.

The bunker fire alarms are small brass cups about one inch by one-half inch partly filled with mercury and are plugged with an insulating plug, in the center of which is lodged a thermometer glass tube, about three-quarters of an inch long. One end of this is submerged in the mercury, while a small metallic needle plugs the other end. The mercury cup is connected with one side of the circuit while the metallic needle is connected to the other. If, by fire, escaping steam or general overheating, the temperature in the bunkers should rise to about 200° F., the mercury rises in the tube, completes the circuit with the metallic point and continues to ring the bells until the evil has been remedied. As each bunker has from three to five or more or more of those alarms, and each one is numbered, one could tell at a glance upon the annunciator, just where the trouble lies.

The search lights vary in size from eighteen inches to thirty inches in diameter, that is, the diameters of their reflectors. Most of the search lights are equipped with parabolic silver amalgamated reflectors. They are used to distinguish things at a distance during the night and also to send signals at great distances. Under favorable atmospheric conditions, intelligence can be conveyed at wonderfully long distances. During the early days of our occupation of the Philippines, the Charleston sent a message from Batangas Bay to the Olympia in Manila Bay, a distance of some 50 miles as the crow flies.

In the base of the search light are two small motors, one of which operates it horizontally and the other vertically, so that in case of bad weather or extreme danger, the search light can be operated either from the bridge or from the conning tower by means of controllers.

The night signal or the Ardois system, consists of four lanterns of some two feet in length each, one-half of which is a ribbed, red glass cylinder and the other is a clear glass ribbed lense.

# EDITORIALS.

THIS issue of THE TECHNIC includes Vol. XIV. and Vol. XV. Owing to lack of financial assistance the 1901 TECHNIC was not published. The articles by Prof. F. C. Wagner and Mr. Alex. E. Kastl were written for last year's volume.

The great demand for the article on "Dynamics of Reciprocating Engines," by Prof. M. E. Cooley, originally printed in the 1888 issue, has occasioned its reappearance here. The text has been revised and all the figures have been redrawn.

Mr. H. C. Ripley the author of "The River and Harbor Works and the Civil Engineer," is a graduate C E. of the U. of M., 1870, and was in the government service from 1870 to 1890 in professional work in the improvement of rivers and harbors. Since 1890 he has made a specialty of river and harbor improvements and marine constructions. He has practiced extensively in Mexico and to some extent in South America. He was a member of the board of engineers on the improvement of Aransas Pass, Texas, and of the board of engineers for the protection of Galveston from overflows from Gulf storms. He was also the recipient of a silver medal and diploma from the Paris Exposition of 1900 as colaborator in an exhibit made by Prof. L. M. Haupt for a method of improving harbors on sandy coasts.

Several excellent contributions have been omitted from this issue for lack of space.

Special acknowledgement must be made of the assistance our alumni and advertisers have rendered us in publishing this number.

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